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This paper presents the first causal estimates of the effect of weather on children's time allocation. It exploits exogenous variations in local weather observed during the random diary dates of two nationally representative cohorts of Australian children whose time-use diaries were surveyed biennially over 10 years. Unfavourable weather conditions, as represented by cold or hot temperature or rain, cause children to switch activities from outdoors to indoors, mainly by reducing the time allocated to active pursuits and travel and increasing the time allocated to media. Furthermore, the effects of bad weather are more pronounced on weekends and heterogeneous across different sub-groups. Our results also provide some evidence of adaptation, as temperature tends to have greater impact not only in winter months but also in colder regions. Overall, the results suggest that extreme weather conditions may diminish children's development and long-term achievements through their effects on children's time allocation.

Key words: Weather, time allocation, time-use diary, children.
JEL classifications: J13, J22, Q54.

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1. Introduction

Time is a scarce resource that is extremely valuable. This is particularly true for children as their time allocation among different activities has been found to affect their development and skills (Gentzkow & Shapiro 2008; Fiorini & Keane 2014; Graff Zivin & Shrader 2016; Del Boca *et al.* 2017) that, in turn, will have enduring impacts on their human capital and their consequential outcomes later in life (Keane & Wolpin 1997; Cunha *et al.* 2005; Huggett *et al.* 2011). While social scientists have spent a considerable amount of effort uncovering how children use their time, so far no study has investigated the effect of weather on children's allocation of time (Guryan *et al.* 2008; Aguiar *et al.* 2012; Andrabi *et al.* 2012).

The current paper attempts to fill in this gap in the literature by examining the causal impacts of weather on children's time allocation. By doing so, this study contributes to a broader understanding of children's time allocation and provides an insight into an important and unexplored channel through which children's development may be influenced (Graff Zivin & Neidell 2013; Dell *et al.* 2014; Carleton & Hsiang 2016; Graff Zivin & Shrader 2016; Hanna & Oliva 2016).

We use individual-level data from over 45,000 time-use diaries of children from two nationally representative cohorts of Australian children whose time-use diaries were surveyed biennially over 10 years to measure the time allocation of children. We then merge these high-quality data with historical weather data from more than 800 monitoring stations throughout Australia and exploit exogenous variations in local weather conditions observed during the random diary dates to estimate the causal impacts of various elements of weather (or, indicators of the latent quality of the "weather") on children's time allocated to several specific types of activities.

These unique datasets allow us to make several contributions to a small literature on the effect of weather on individual's time allocation. First, this paper is the only study, so far, to analyse the impact of weather conditions on the time allocations of children. To date, there have been only two studies, using US data, that have examined the impact of weather on time allocation. Both of those studies (Connolly 2008; Graff Zivin & Neidell 2014) were studies of adult time use. A study on the determinants of child time allocation is important because individuals of different ages may respond to weather conditions differently. More importantly, as indicated above, children's allocation of times across various activities has been shown to have important implications for their development (Fiorini & Keane 2014; Graff Zivin & Shrader 2016; Del Boca *et al.* 2017). A better understanding of the effect of

weather on children's time allocation may help to formulate policies that aim to promote better development outcomes for children. These policies may be of increasing relevance for regions that are affected (either adversely or favourably) by climate change (Dell *et al.* 2014; Graff Zivin & Shrader 2016).

Second, unlike the two extant US studies, which exclusively examine the impact of one element of weather (such as precipitation (Connolly 2008) or temperature (Graff Zivin & Neidell 2014)), this paper investigates several weather elements, including precipitation and temperature, at the same time. By using rich measures of the prevailing weather conditions taken at local area levels,[1] we are able to explore their joint impact on children's time allocation. Third, by using Australian data, we are able to examine whether previous US findings about the effect of weather on time allocation hold on a different continent (i.e., Australia). As will be shown in this study, average temperature is higher in Australia than in the US. It has been proposed that people who live in more temperate regions may, *ceteris paribus*, be more tolerant to heat (Graff Zivin & Neidell 2014). These datasets we have assembled enable us to test this hypothesis and to compare our results to those obtained in the US (albeit on adult samples).

Also, whereas the two previous US studies on time allocation and weather conditions used cross-sectional time-use surveys (and hence observed only one time-use survey per respondent), this study employs a rich source of panel data which tracks time-use diaries of the same children over time or: in many cases, for two time-points (*viz.*, one time-use diary collected for a weekday and one collected for a day at the weekend) in a particular year. The panel nature of our data allows us to examine at least three unexplored important aspects of the impact of weather on time allocation. First, we are able to document the evolution of (and hence the impact of weather on) time allocation of the same individuals over a long and important period of child development, from birth to 14/15 years of age. Second, for the first time in this literature, we are able to distinguish the effects of weather on time allocation on weekdays and at weekends.[2] Previous studies do not make this potentially-important distinction, probably due to the small number of diaries that were recorded on weekends in

[1] This also limits the potential omitted variable bias. Note that Graff Zivin and Neidell (2014) also have other weather elements such as precipitation, humidity and minimum temperature in their models. Unfortunately, they do not present estimation results for these weather variables.

[2] In this study, weekend days include Saturdays, Sundays, public holidays and school holidays while weekdays include the remaining days. We use the response "a holiday or a family celebration" to the question "What kind of day was described in the diary" to identify public and school holidays for diaries completed in waves 1 to 3. Because the above question is not asked in waves 4 or later, we use the official school and public holidays set out by the state/territory to identify public and school holidays for diaries conducted in waves 4 to 6.

their datasets (Connolly 2008; Graff Zivin & Neidell 2014). The distinction may be important as differences between the time allocations observed on weekends and weekdays may be expected for theoretical reasons that concern the time allocation budget constraint. Specifically, most children and their parents may be expected to be more constrained in their time allocations during the week due to, for example, school schedules and/or parental work arrangements. Thus, children (and their parents) may have more freedom to adjust to weather conditions on weekends than weekdays. As such, weather conditions may be expected to have more pronounced marginal impact on children's time allocation on weekends.

Third, this paper uses panel data to control for unobserved individual heterogeneity. Although variations in local weather conditions observed during the random diary dates are plausibly exogenous, estimates of weather in the time allocation regression still may not be causal due the possibility that the choice of living location is endogenous. Specifically, if people self-select into different climates based on the responsiveness of their behaviours to weather conditions, the weather conditions become endogenous with respect to the model studied (Rappaport 2007; Albouy *et al.* 2016; Sinha *et al.* 2018). This paper thus provides an effective test of the robustness of the previous studies in which findings are based on cross-sectional data, that therefore could not account for unobserved individual fixed effects, including living location preferences (Graff Zivin *et al.* 2018).

We present robust evidence that unfavourable weather conditions, as measured by cold or hot temperature or rain, cause children to shift their activities from outdoors to indoors, mainly by reducing the time allocated to active or travel activities and increasing the time allocated to media activities. We additionally present evidence that daily maximum temperature has non-linear impacts on the time children allocate to such activities. We also show that the impact of weather is more pronounced on weekends than weekdays: a new finding which is consistent with the view that children are likely to have more flexibility adjusting their time allocations on weekends.

Our results also show significant heterogeneity in the effects of weather on children's time allocation. For example, temperature has a much stronger impact for children with asthma while precipitation has no statistically significant effect for them. Our results additionally provide suggestive evidence for acclimatization because children living in colder regions or surveyed in colder months are more sensitive to warmer temperatures. We also find other indicative evidence for short-run adaptation to weather conditions because children appear to shift activities to more favourable times of the day.

The remainder of the paper is structured as follows. Section 2 describes the data and provides some descriptive analyses on the effects of weather on children's time allocation. Section 3 presents our empirical regression models and Section 4 discusses the regression results. Section 5 reports results from various robustness checks and Section 6 presents heterogeneous weather impacts. Section 7 discuss our results as well as their potential welfare implications. Finally, Section 8 concludes.

2. Data and descriptive statistics

2.1. Data

2.1.1. Longitudinal Study of Australian Children data

The Longitudinal Study of Australian Children (LSAC) is a biennial nationally representative survey that began in 2004. The sampling frame consists of all children born between March 2003 and February 2004 ("Birth" or "B"-Cohort, 5,107 infants aged 0–1 year in 2004) and between March 1999 and February 2000 ("Kindergarten" or "K"-Cohort, 4,983 children aged 4–5 years in 2004). We use the latest release of the LSAC data where children of both cohorts have been surveyed six times over 10 years. For both cohorts the survey collected a very rich set of information about children's development and the demographic and socio-economic backgrounds of their parents. These data will be used with regard to the control for all possible confounders of childhood time allocation. In addition, the LSAC collected time-use diaries of children from both cohorts which we will use to measure children's time allocation among various activities.

2.1.2. Time-use diaries

Time-use diaries (TUD) were surveyed biennially over up to six waves or 10 years of children from both cohorts. The data thus allow us to study the time allocation of children from birth age (0/1 year old) to 10/11 years old for B cohort children or from pre-school ages (4/5 years old) to adolescence (14/15 years old) for K cohort children. Several changes to the TUD during this study period are worth discussing. First, from wave 1 to wave 3, families were given two TUDs to complete each wave so each child had up to two TUDs (one on a weekday and one on a weekend day). However, from wave 4 to wave 6, each child was given one TUD to complete, on either a weekday or a weekend day, each wave. Second, while the parent completed the TUD in the first three waves, the study child was supposed to complete the TUD in waves 4 to 6. Third, activities that the study child undertook during the time diary day are listed slightly differently across waves to reflect age-specific activities. Fourth, while

children's activities are reported according to the 96 15-minute periods of each 24-hour block in the first three waves of data, children's activities are listed in the form of an "activity episode" diary in the last three waves of data (See Appendix Figure A1, Appendix Figure A2 and Appendix Figure A3 for examples of the diary and its coding). Finally, while K cohort children are asked to complete TUD in all survey waves, B cohort children are not asked to fill in TUD in waves 4 and 5 (when the children were 6/7 and 8/9 years old, respectively).

2.1.3. Activities

As was noted previously, activities that the child undertook during the time diary day are listed slightly differently across waves and the number of pre-coded activities increases as the child ages (ranging from 22 activities in wave 1 for B cohort to 135 activities in wave 6 for both cohorts). Therefore, we aggregated the pre-coded activities into a smaller set of activities. Our aggregating is based on previous studies (Corey *et al.* 2014; Fiorini & Keane 2014) with some necessary variations to make activities reasonably comparable during 10 years of development of children from the two cohorts. We also attempt to distinguish activities that have been shown to have important implications to the children's development (Malamud & Pop-Eleches 2011; Fairlie & Robinson 2013; Fiorini & Keane 2014; Graff Zivin & Shrader 2016; Del Boca *et al.* 2017). We grouped activities in such a way as to render activity groups that are likely to be affected similarly by weather conditions.

The resulting list of aggregated activities includes: sleep, personal care, school, education, active, media and travel. Specifically, sleep includes time spent on sleeping and napping. Personal care consists of awaking in bed, eating/drinking, showering/bathing and doing non-active non-educational activities, household chores or (paid and unpaid) work. We record activities related to the child's schooling and their education separately. Schooling relates to time allocated to organised school lessons or day care centre/playgroup while education refers to the time spent on the child's own educational activities outside school, including reading or being read to, doing homework and attending private lessons. We include time spent on walking, cycling or attending organised sport/physical activities as active activities. Media includes time watching TV programs or movies/videos, playing video games, using computer and internet (unrelated to doing homework) and communicating via electronic devices. Travel refers to time spent in transit both by private and public transport. Details of each activity classification appear in Appendix Table A1 and Appendix Table A2.

It should be noted that, because children may undertake several activities concurrently, the total of time allocated to different activities during the diary date may exceed 24 hours. Given

that the respondent was not asked to distinguish between the main activity undertaken and any activities being undertaken simultaneously, we follow Fiorini and Keane (2014) and do not differentiate between the main and secondary activities. Furthermore, we do not distinguish the child's activities by who is present during each activity because the available information does not provide any clarity about the actual participation intensity of the nearby person(s) (if any) with the child (Baxter 2007).

While our aggregated activities may be affected differently by weather conditions, we also follow Graff Zivin and Neidell (2014) to construct a separate variable indicating whether an activity was undertaken outdoors. Our data are particularly appealing because they include an indicator of whether activities were performed outdoors, indoors, or both. We therefore use this indicator to identify the time spent outdoors. We also assign a small fraction (about 3% of all activities with indoor/outdoor) of activities reported as undertaken both indoors and outdoors as outdoors and use this direct indicator to identify the time spent outdoors. Possibly because of their inherent outdoor/indoor nature, a question about where the activity took place was not asked for some activities such as "gardening, putting out the bin" or "taking pet for a walk" from wave 4. As these activities are inherently outdoor activities they were coded as such for our purposes in this paper. (See the last panel in Appendix Table A1 and Appendix Table A2 for detailed coding of outdoor activities.[3])

2.1.4. Weather data

Our historical weather data come from the Australian Bureau of Meteorology (BOM). These data contain detailed information about meteorological elements at all monitoring sites throughout Australia.[4] We use the latitude and longitude of over 800 monitoring stations and that of the postcode centroid where the child lives in to identify the spatially-closest three weather stations to the child's residential postcode centroid.[5] We thereby assign weather elements from the three monitoring stations as the child's local weather conditions. We use the geographic centroid inverse distance weighted average of weather elements from three nearest weather stations rather than using weather elements from the closest weather station as suggested by Hanigan, Hall, and Dear (2006).

[3] Activities undertaken at "School, after/before school care" or "School lessons" are not identified according to this definition.

[4] See Appendix Figure A5 for distribution of weather stations. Due to confidentiality requirements, we are unable to publish the residential postcode centroids in Appendix Figure A5.

[5] We use the unconfidentialised version of the LSAC allowing for identification of postcode of residence for each year of the survey. Postcodes are the finest geographical identifiers available in our data.

Our spatial matching results show that, on average, the first-, second-, and third-closest weather stations are within around 7, 15, and 19 miles, respectively, of the child's residential location. Most of the cases in which we cannot use weather variables from the closest weather stations arise because the required weather variables are not available on the diary dates. Although our data are nationally-representative and Australia is a vast country, our finely spatial distance matching ensures that children's activities in our study are influenced by local weather conditions.

2.1.5. Weather measures

Our first weather measure is temperature.[6] Although temperature is customarily measured in degrees Celsius (^{0}C) in Australia, we measure temperature in degrees Fahrenheit (^{o}F) in order to render our results comparable to those produced by the US study of Graff Zivin and Neidell (2014). This temperature transformation conveniently also renders all negative ^{o}C temperature values in our data to positive ^{o}F temperature values, enabling us to introduce a quadratic form of temperature in regressions to examine the possible non-linear impact of temperature on time allocation.[7] This is beneficial as previous studies show that temperature may have non-linear impacts on human performance (Pilcher *et al.* 2002; Hancock *et al.* 2007; Trudeau *et al.* 2016), adults' time allocations (Graff Zivin & Neidell 2014) or overall economic productivity (Burke *et al.* 2015). We also follow Graff Zivin and Neidell (2014) to consider the effects of both daily maximum and minimum temperatures on children's time allocation.

Appendix Figure A6 – Panel A represents the distribution of daily maximum and minimum temperatures between 2004 and 2014 for those postcode-dates from which we have observations in our final sample. Average daily temperature ranges (minimum at 48^{o}F and maximum at 67^{o}F) in this study are quite similar to those reported in the US study by Graff Zivin and Neidell (2014). It should be noted that while diary dates in the US data used by Graff Zivin and Neidell (2014) are concentrated in summer months, those in our data are

[6] Our data also contains dewpoint temperature and station level pressure. However, we do not use dewpoint temperature because it is constructed using temperature and humidity for both of them we control in regressions. Similarly, station level pressure is not used because it entails a lot of missing information. Using wind gust in place of wind speed produces similar results.

[7] This specification was used in the main analysis to keep the results manageable and more importantly, as will be demonstrated below, the results are robust to the use of an alternative degree-day binning framework.

concentrated in non-summer months,[8] indicating generally warmer weather conditions in Australia than in the US.

The second weather measure is daily precipitation (in inches). Appendix Figure A6 – Panel B shows that precipitation is observed at some point on approximately 45% of diary days.[9] Appendix Figure A6 additionally reveals that weekends and weekdays appear identical in the distribution of daily temperature or rain, suggesting these weather conditions are not a function of our defined weekdays or weekends. Other weather variables included are relative humidity (reported as a percentage), wind speed (in miles per hour) and wind direction (in degrees to the north). For these weather variables, we introduce their daily minimum and maximum values in the regressions.

We also control for daylight hours in all regressions because it is plausibly associated with time allocation. To calculate the hours of daylight for every postcode and diary date we use the sunrise and sunset time estimated from an astronomical formula proposed by Forsythe et al. (1995) and uses the latitude of the postcode centroid. Daylight is identified as the length of time between sunrise and sunset time where sunrise/sunset is identified when the top of the sun is apparently even with the horizon.

2.2. Sample

We exclude TUDs with obviously incorrect entries, incomplete information, incorrect diary time entries, or duplicated diary dates. We also exclude TUDs with missing information on weather and basic explanatory variables that we control for in the regressions (see Section 3). Our final sample includes 45,347 complete time-use diaries from 6 waves and 8,569 unique children. Among these, 4,272 children come from the LSAC B cohort and about three quarters (33,600) of TUDs were completed by parents. Importantly, in line with the sampling design of the LSAC (AISF 2015), the number of TUDs is distributed equally by weekdays/weekends, with 22,944 TUDs completed on weekdays and the remaining 22,403 on weekends. Across all waves, including waves 4-6 when children completed their TUDs, the number of TUDs is also evenly spread by weekdays/weekends.

[8] To maximise the return rates, LSAC surveys were implemented outside school summer holidays (December, January and February), including Christmas and New Year holidays (AISF 2015).
[9] Defining a rainy day as a day with 0.10 inches of rain or more as has been done by Connolly (2008) results in about 14 % of time diary days classified as rainy days.

2.3. Sample representativeness

In the LSAC survey, the TUD dates are likely to be random because these dates were selected by the interviewers to ensure a random distribution of weekdays and a random distribution of weekend days (Baxter 2007). The realization of weather on different diary dates is also plausibly random. While the degree of nonresponse bias with respect to socio-economic backgrounds has been assessed (Baxter 2007; Corey *et al.* 2014), a related concern in our study design is that the weather could affect participants' propensity to complete a diary that is then included in our final sample. We examine this possibility by running a probit model where the dependent variable is equal to one if the child is in our sample and zero otherwise. The explanatory variables are basic demographic characteristics and the weather variables on the scheduled time diary dates. The scheduled time diary dates are available for all children who completed the main LSAC surveys, regardless whether their time diaries are completed and hence were included in our final sample.[10] Because we only know the scheduled diary dates from wave 4, we apply this regression to a sample of children surveyed in wave 4 or later. Appendix Table B1 presents the results. There is evidence of statistically significant selection on some observables. For instance, children in our sample tend to be younger, are more likely to be female, or healthier, or come from families with more advantageous socio-economic background (as measured by living in an owned home, living with both parents or having more educated mothers). However, the pseudo-R^2 value is small, indicating that selection on observable characteristics is quantitatively weak. Among all included weather variables, only the estimate of temperature is statistically significant. However, the estimate is relatively small (its coefficient reported in marginal effect is -0.0065) and statistically significant at the 10% level. More importantly, the estimates of all included weather variables are jointly statistically insignificant,[11] alleviating concern that our results may be driven by sample selection due to weather conditions.

2.4. Descriptive analyses

Table 1 suggests that the time allocated to some activities apparently differs by weekdays and weekends. Specifically, children spend more time on active and media activities and hence less time on school on weekends than on weekdays. They also appear to spend more time outdoors on weekends (172 minutes) than on weekdays (104 minutes). Appendix Figure A4

[10] Specifically, from wave 4, the scheduled time diary date is the day prior to the survey date which is known for all participants.
[11] P value of a Chi square test for whether the estimates of all included weather variables are equal to zero is 0.42 (See Appendix Table B1).

which represents allocation of children's time among various activities over a 24-hour period also indicates a similar time-use pattern by children. In particular, we still observe higher frequencies of time allocated to active and media activities or outdoor activities on weekends than on weekdays, especially in the 8-18 time windows. Appendix Figure A4 also shows that children tend to undertake a particular activity at specific time windows. For instance, sleep time has the usual U-shape pattern. There are two daily spikes in personal care activities, with a surge of morning activities starting in the one hour segment from 7:00 and another surge of night activities in the two hour segment from 18:00. As expected, school activities are most frequent in the 9-16 time windows during weekdays. Consistent with school activities, travel activities, no doubt associated with travelling to and from school, during weekdays are most frequent before the school opening hour (9:00) or after the school closing hour (15:00). Similarly, active pursuits, which are often undertaken outdoors, are most frequent from 9:00 to 17:00. Appendix Figure A4 also reveals that children tend to have more freedom on weekends than weekdays since they appear to wake up later and hence undertake active and media activities later on weekends. These time allocation patterns lend face validity to the diary data entries, but they also suggest that separate analyses of time allocation by weekends and weekdays may be warranted.

[Table 1 around here]

3. Empirical models

3.1. Theoretical backgrounds

This study is motivated by various theoretical frameworks which explain how individuals allocate their time (Becker 1965; Lucas & Rapping 1969; Gronau 1977). In our case, a child is hypothesized to decide on how to allocate the time among weather-dependent (such as outdoor) and weather-independent (e.g., indoor) activities to maximize utility given constraints. Adopting an intertemporal theoretical framework of time allocation akin to that proposed by Connolly (2008), the child's utility depends on current and future weather-dependent activities.[12] The child's intertemporal budget constraint is a function of current and future returns to weather-independent activities and a discount rate. Children may be constrained by the horizon over which they can locate their activities, probably because of school schedules. Furthermore, as young children's activities are often associated with that of their parents, the children's time allocation is reasonably subject to constraints faced by the

[12] An alternative static theoretical framework of time allocation, similar to the one proposed by Becker (1965), would produce similar implications about the impact of weather on children's time allocation.

parents, including their work arrangements (Connolly 2008; Graff Zivin & Neidell 2014). There is also another time constraint associating with the fact that children only have 24 hours per day to spend on all activities.

In the child's utility maximization problem described above, weather enters the utility function directly as it affects the utility obtained from weather-dependent activities. If we assume that unfavourable weather conditions make weather-dependent activities less enjoyable, the above framework suggests that: if the weather is nicer today than it will be tomorrow the child will increase the weather-dependent activities today and decrease future weather-dependent activities. Furthermore, as most children and their parents may be more constrained in their time allocations during the week due to school schedules and/or parental work arrangements, weather conditions are expected to have more apparent impact on children's time allocation on weekends.

3.2. Econometric models

The following econometric model is employed to investigate the impact of weather on the time allocated to activity j by the child i:

$$Y_i^j = \alpha^j + Z_{p(i),t(i)}^j \beta^j + X_{it}^j \gamma^j + p_i^j \delta^j + \tau_i^j \epsilon^j + \varepsilon_i^j \qquad (1)$$

where the variable Y^j is the amount of time allocated to activity j on the observed time diary date t of the child i who resides in the postcode p. X_{it}^j is a set of control variables and ε_i is the random error term.

When selecting controls (X_i^j), besides common variables representing the child's characteristics such as age, gender, Aboriginal status and health status, we wished to account for parental time and income constraints. As proxies for the parental time endowment we use dummies to indicate maternal employment status (working full-time, working part-time or unemployed), maternal health status and household structures (whether the child lives with both biological parents, the number of siblings at different ages). To capture parental income, we include household income and home ownership status[13] (living in a rental or an owned home) in all regressions. Maternal education is likely to affect the child's time allocation, either through its relationship with maternal time allocations with the child or through its

[13] Following some previous studies using the LSAC data to investigate the intergenerational transmission of human capital (Le & Nguyen 2017, 2018), we mainly focus on the characteristics of the mother of the child because these characteristics are more widely available for mothers than for fathers. We also experimented with the whether the residential home is a separate house and found statistically insignificant impact of this variable. This variable has some missing values so we do not include it in the final regressions.

effect on the child's time preferences (Guryan *et al.* 2008). We therefore control for maternal education as well as migration status. We control for a rich list of local level variables that may be correlated with weather and potentially children time allocations.[14]

We include in τ_i^j a series of day-of-week dummies to capture possible changes in time allocation throughout the week, and month and year indicators to control for trends in weather and time use over seasons and years. Including year dummies (which also represent the wave where the TUD was recorded) also helps us to account for the differences in diary structures across waves that were discussed in Section 2. Finally, postcode dummies (for about 300 postcodes in our datasets) are included in the regression to capture all time-invariant observable and non-observable factors within postcodes (p_i^j) that may influence the child's time allocation. Therefore, our estimates of the impact of weather on time allocations (β^j) are identified from daily fluctuations in weather within a postcode.

We estimate equation (1) separately for each of the aforementioned grouped activities. As mentioned previously, in order to account for multi-tasking, we do not impose any restriction on the total time spent on all activities during the time diary date. We also estimate equation (1) separately for activities undertaken during weekdays and weekends. For ease of interpretation, we apply the Ordinary Least Squared (OLS) regression method because the proportions with zero time duration for some particular grouped activities appear to be small (See Appendix Table B5).[15] We estimate robust standard errors that allow for *two-way* clustering at the postcode and month - year level to deal with any concerns that weather may be spatially correlated across postcodes within a given year - month and additionally serially correlated within a postcode over time.[16]

[14] Local variables include percentages of individuals of various ages, year 12 completions, working, speaking English, being born in Australia, or having an Aboriginal/Torres Strait Islands origin in linked areas, percentages of households with household income less than AU$1,000/week in linked areas, a metropolitan dummy and state/territory dummies.

[15] We apply an OLS regression to the pooled sample of all TUDs in the main analysis for three reasons. First, we would like to make our results comparable with that in the previous US studies which use the same specification (Connolly 2008; Graff Zivin & Neidell 2014). Second, applying an individual fixed effects (FE) specification results in a loss of 3,092 observations (about 7% of the original sample of 45,347 TUDs) because we must observe an individual child with at least two TUDs recorded during either weekdays or weekends to apply the FE regression technique. Third and most importantly, one of our robustness checks (Sub-section 5.4) shows that the FE results are largely similar to the OLS results.

[16] This two-way clustering is not clearly more conservative than clustering on the postcode level alone; in some cases, two-way clustering reduces the standard errors and while in other cases, it increases the standard errors. Nevertheless, other alternative clustering approaches such as clustering on the individual child or clustering on the postcode level produce similar results.

4. Empirical regression results

4.1. Impact of weather on children's time allocation

The effects of various weather elements on children's time allocation are reported in Table 2.[17, 18] We begin with a focus on the impacts of daily maximum temperature. The results (reported in the first two rows in Table 2) show that the daily maximum temperature has statistically significant (at least at the 5% level) effects on the time allocated by children to active, media, travel and outdoor activities (only). Furthermore, the impact of temperature on time allocated to these activities is non-linear: the estimates of the quadratic-term for temperature are also highly statistically significant (at least at the 5% level) and have the opposite sign to the estimates of the first-order term for temperature. In particular, the results show the relationship between temperature and active, travel and outdoor activities follows an inverted U-shaped pattern while the relationship between temperature and media activities exhibits a U-shaped pattern (See Figure 1 – Panel A). Intuitively, the results suggest that time allocated to active, travel and outdoor activities first increases with temperature before starting to decrease after some inflection point (more on this below). By contrast, time spent on media activities (weekends only) first deceases with temperature before starting to increase after 67ºF.

[Table 2 and Figure 1 around here]

The results in Table 2 and Figure 1 also exhibit heterogeneity in the temperature impact by weekdays and weekends. Specifically, temperature has a statistically significant impact on media and travel activities undertaken on weekends only (also see Figure 1 – Panel B). Furthermore, when the estimates are statistically significant for both weekdays and weekends (i.e. active and outdoor activities), they are of a larger magnitude for weekends. Graphically, it is illustrated in Figure 1 – Panel B that the absolute marginal effects of temperature on time allocated to these activities are uniformly greater on weekends. Particularly, at the lower end of the daily maximum temperature distribution, the impact of a one ºF increase in

[17] Appendix Table B2 provides some preliminary evidence on the impact of weather conditions on how parents report whether or not the weather conditions that prevailed on the diary date were good enough to engage in outdoor activities. It shows that parents are less likely to report so on days with unfavourable weather conditions (as measured by days with temperature at the lower or higher ends of the distribution, rain, more humidity or stronger wind). These results thus provide an external validity check for our spatial matching of local weather conditions. Appendix Table B2 also suggests that, conditional on weather conditions, parental perceptions about the impact of weather is also statistically significantly correlated with some characteristics of the child (such as gender and health condition) or the parent (e.g., health status and migrant background), suggesting that the effects of weather may differ according to these characteristics.

[18] Estimation results for other control variables are reported in Appendix Table B3.

temperature from 26ºF on time allocated to outdoor activities is roughly three times greater on weekends (an increase of 7.22 minutes) than on weekdays (an increase of 2.46 minutes). Likewise, at the higher end of the daily maximum temperature distribution, an increase of one ºF from 100ºF has a negative impact on time allocated to outdoor activities and the impact is about 52 times (in absolute value) greater on weekends (a reduction of 2.06 minutes and the impact is statistically significant at the 1 % level) than on weekdays (an increase of 0.04 minutes and the impact is statistically insignificant).[19] By contrast, the turning points are always lower for weekends. In particular, while the turning point for active activities is 87ºF for weekends, it is 89ºF for weekdays. Similarly, the turning point for outdoor activities is 84ºF for weekends; it is as high as 101ºF for weekdays. Our finding that temperature has a greater impact on children's time allocations on weekends is consistent with our hypothesis that children may have more freedom to adjust to weather conditions on weekends than weekdays. To the best of our knowledge, this is a novel finding.

Results from row 3 in Table 2 suggest that daily minimum temperature also has a statistically significant and negative effect on children's time allocated to some activities such as active (weekdays only), or outdoor (weekends only) activities. However, as compared to the estimates of daily maximum temperature, the estimates of daily minimum temperature are much less pronounced, both in terms of their statistical significance levels (the highest statistical significance level is 5 %) and magnitudes.

Turning to the impact of daily precipitation (Table 2 – row 4), we also observe some statistically significant (at least at the 5 % level) estimates of this weather element on children's time allocated to sleeping, school, active, media, travel and outdoor activities. In particular, children respond to daily precipitation by sleeping more (weekdays only), spending more time on media activities (weekends only) and participating less in school (weekends only), active and outdoor activities. We also find some heterogeneity in the impact of daily precipitation by weekdays and weekends because for some activities the estimates are statistically significant for weekdays (sleeping and travel) or weekends (school and media) only. Furthermore, although daily precipitation has a statistically significant and negative impact on time allocated to outdoor activities undertaken on both weekends and weekdays, the impact is slightly greater for weekends (i.e. an increase of one inch in daily precipitation is associated with a decrease of 24.52 minutes in time spent outdoors) than weekdays (22.90 minutes). The finding that daily precipitation has more pronounced effects

[19] In our data, while most of TUDs were completed in non-summer months, there are 82 days, of which 46 are weekdays, with maximum temperature of 100 ºF or higher.

on weekends (i.e. more statistically significant as in the estimates on school and media activities or of a higher magnitude as in the estimates on outdoor activities) is also consistent with the hypothesis that children are likely to have more flexibility adjusting their time allocations on weekends.

It should be noted that our findings on the impact of daily precipitation and temperature are not directly comparable to those presented by Connolly (2008) or Graff Zivin and Neidell (2014) due to our apparent differences, for example, in the grouping of activities undertaken by individuals of very different ages. (Of course, the time allocations of those adults who are parents, and those of their children, should be expected to be highly correlated for obvious reasons.) Despite the differences between these three studies they do, however, appear to share some common findings. For instance, one of the findings in this paper that children spend less time on active pursuits, mostly consisting of "leisure" activities, on rainy days is in line with the finding presented by Connolly (2008): working age males allocate less time to leisure activities on rainy days. As another example, the current study and that by Graff Zivin and Neidell (2014) both uncover an inverted U-shaped relationship between daily maximum temperature and time spent outdoors. However, it is interesting to observe that the turning points in the impacts of temperature on outdoor activities found in this study (84^{o}F for weekends and 101^{o}F for weekdays) are much higher than that found in the US study (76^{o}F-80^{o}F). Again, the differences in climates and individuals between the two studies may explain the differences in turning points. The higher turning point for Australia when viewed with the fact that Australia has warmer climate thus give support to the thesis that individuals who live in more temperate climates may also be more tolerant to warmer temperatures.

The next seven rows from 5 to 11 of Table 2 turn our attention to the impacts of other weather characteristics on children's time allocation. Most of the estimates are not highly statistically significant. However, two noticeable exceptions are observed. First, the maximum daily wind speed has a statistically significant impact (at least at the 10 % level) on the time allocated to outdoor activities: children tend to switch to indoor activities when wind is stronger. We also observe that maximum daily wind speed has stronger effects on weekends since the estimates are more statistically significant (at the 1 % level as compared to the 10 % level on weekdays) and about three times greater in magnitude for weekends (=-0.63/-0.23). Second, hours of daylight on the diary dates are also found to influence how children allocate their time across some activities. Again, the impact of daylight appears to be different by weekdays and weekends. Specifically, on weekends, children allocate slightly

more time to outdoor activities when daylight durations are longer. By contrast, on weekdays, children respond to longer daylight by spending more time on school-related activities and hence less time on sleeping and travel. Our finding of the statistically significant impact of temperature and precipitation and little impact of other weather variables such as wind direction and humidity on outdoor activities are consistent with the parental perception about the impact of weather on outdoor activities found earlier (Appendix Table B2).

In sum, our results so far reveal that unfavourable weather conditions (i.e. cold or hot temperature, or rain) cause children to switch their activities from outdoors to indoors, mainly by reducing the time allocated to active or travel activities and hence increasing the time allocated to media activities. We also present evidence that daily maximum temperature has non-linear impacts on the time children allocate to active, media, travel and outdoor activities. The finding that temperature has non-linear impacts is comparable to that presented in previous studies on adult individuals' time allocations (Graff Zivin & Neidell 2014), human performance (Pilcher *et al.* 2002; Hancock *et al.* 2007; Deschênes & Greenstone 2011; Trudeau *et al.* 2016) or economic production (Burke *et al.* 2015). We additionally uncover that the impact of weather is more pronounced on weekends than weekdays, a finding which is in line with the view that children may have more freedom to adjust to weather conditions on weekends. Because we have found more statistically significant impacts of daily maximum temperature and daily precipitation on children's time allocation, we will focus on these weather elements in the rest of the paper.

4.2. Adaptation

Above, we have investigated the effects of contemporaneous weather conditions on children's time allocation. This may be characterised as an examination of the effect of weather on the "intensive margin" in respect of child time allocation. Yet it is also possible that children may shift activities to days with more suitable weather conditions (inter-day substitution) or reschedule activities to more favourable times of the day (intra-day substitution). In other words, concentrating only on the intensive margin does not address the question of whether or not weather conditions affect the extensive margin (e.g., the total time allocated to active pursuits). In this section we explore the possibility of short-run adaptation/acclimatization to shed light on the question of the effect of weather on the extensive margin.

We first follow Graff Zivin and Neidell (2014) to investigate the scope of inter-day substitution by including lagged or leaded weather conditions as well as current weather

conditions in equation (1). If children shift activities across days, we then expect unfavourable lagged (leaded) weather conditions to increase the time allocated to current activities. We then examine the possibility of intra-day adaptation by exploring the impact of daily weather conditions on activities undertaken within different time windows during the day.

Table 3 reports estimates of current and lagged (measured over the previous 6 days) weather variables on children's time allocation.[20] The results show little evidence of inter-day substitutions with respect to temperature since estimates of almost all lagged temperature variables are statistically insignificant. On the contrary, the estimates of lagged precipitation are negative and statistically significant for some activities, indicating that precipitation during the last 6 days actually reduces the time children spent outdoors (on weekdays only), mainly by reducing active time and hence increasing school and education time. Although this temporal impact of precipitation does not support the thesis that inter-day substitution preserve time allocations across activities, it is consistent with the view that wet weather in previous days also makes current conditions for outdoor related activities less favourable (e.g. if the playground is still wet in the following days). Turning to the impact of leaded weather (measured over the following day, results are reported in Appendix Table B4), we also find little evidence about inter-day substitutions in relation to temperature because all estimates of leaded temperature are statistically insignificant. Although the estimates on leaded precipitation are not highly statistically significant, they usually have the same sign as that of current precipitation, a pattern which is highly consistent with the ideas that precipitation may be highly correlated across adjacent days. Again, the estimates of leaded precipitation are not interpreted as evidence of inter-day substitution with respect to precipitation. Thus, we do find evidence that precipitation not only affects the intensive margin but the extensive margin with respect to children's time allocations.

[Table 3 around here]

Following Graff Zivin and Neidell (2014), we then explore whether children shift the timing of activities within the day in response to weather conditions by estimating the weather impacts by twilight and daylight (results are reported in Table 4). The estimates of daily maximum temperature convey that time allocated to active, media, travel and outdoor

[20] Measuring weather over the previous day or the same day in the week before the diary date produces similar results. Consistent with the baseline estimates reported in Section 4, estimates of weather variables on other grouped activities are usually statistically insignificant. For brevity, they are not reported and will be available upon request.

activities is much more responsive to temperature (both in terms of the magnitude and statistical significance level) during daylight than twilight. Furthermore, the differences in temperature impact by daylight and twilight are statistically significant, particularly for active, media and outdoor activities undertaken on weekends. The greater effects of temperature observed during daylight are consistent with the fact that daily temperature usually reaches its peak within these time windows. These patterns are suggestive of the view that children shift activities to more favourable times of the day. Table 4 also shows that the effects of precipitation are usually more pronounced during daylight, suggesting that the precipitation effects observed earlier in the baseline analyses are mainly driven by activities undertaken within these time windows. Our evidence on the short-run adaptation of children to weather conditions is in line with that for US adults (Graff Zivin & Neidell 2014). It is also consistent with evidence of avoidance behaviours to air pollutions found in the literature (Neidell 2004; Currie *et al.* 2009; Neidell 2009; Moretti & Neidell 2011).

[Table 4 around here]

5. Robustness checks

This section presents the results of a number of robustness checks of our estimation strategy. A first set of robustness checks involves testing our baseline model against alternative sample choices (Sub-sections 5.1, 5.2 and 5.3). We also check the robustness of our results using different econometric models for the time allocation variables in Sub-sections 5.4 and 5.5. The third set of tests (Sub-section 5.6) is designed to gauge the sensitivity of the results when alternative functional forms of weather variables are employed.

5.1. Results for a pooled sample of weekdays and weekends

For comparison purposes with the US studies (Connolly 2008; Graff Zivin & Neidell 2014), we also report weather effects where we do not separate the sample by weekdays and weekends. Results from this exercise (reported in Appendix Table B6) confirm the well-defined weather impacts on children's time allocation found earlier in Section 4. Specifically, daily maximum temperature and daily precipitation remain the main weather elements driving children's time allocation, particularly to active, media and outdoor activities. Furthermore, as expected, the estimates from the pooled sample are bounded between the estimates obtained separately for weekdays and weekends. Finally, the estimates for the weekend dummy are highly statistically significant (at the 1% level) in all regressions, supporting our empirical strategy to examine children's time allocation separately by weekends and weekdays.

5.2. Excluding time-use diaries completed on unscheduled dates

In the baseline models, we used a sample of all completed TUDs with about 17 % of them completed not as scheduled.[21] Concerns may arise because the unscheduled diary dates may not be random. We check the robustness of our results by excluding TUDs completed on unscheduled dates and find that the results (reported in Appendix Table B7) are very similar to those obtained from our baseline specification.

5.3. Including only Saturdays and Sundays in weekends

Above, weekends are defined to include Saturdays, Sundays, public holidays and school holidays to reflect the fact that children typically do not attend school during these days. It is possible that, on school holidays, parents may not be on holidays and this may influence the time allocation by parents and children (e.g., resulting in some children being in "out-of-school care", which is provided by many schools during school holidays for such contingencies). We check the sensitivity of our results by including only Saturdays and Sundays in weekends. The results (Appendix Table B8) are quantitatively similar to those reported above.

5.4. Controlling for individual fixed effects or excluding the individual and household level explanatory variables

As discussed in Section 1, if parents self-select into different climates based on the responsiveness of their children's behaviours to weather conditions, then the climate becomes endogenous with respect to the children's time allocation (Rappaport 2007; Albouy *et al.* 2016; Sinha *et al.* 2018). One effective way to test whether individual residential location preferences affect our results is to directly control for such preferences (if any) in the regression. We do so by applying an individual child fixed effects (FE) regression technique which controls for individual fixed effects, including individual residential location preferences, to equation (1). Results of this experiment are reported in Appendix Table B9. While the sample size is reduced by the inclusion of FEs, the results are largely similar in terms of the magnitude and statistical significance to the pooled regression results reported in Table 2. The similarity between the two specifications (i.e. pooled and FE) indicates that (i) we control for a rich set of explanatory variables in the pooled model, (ii) there is little evidence of location selection in our data, or (iii) both. As suggested by Dell *et al.* (2014), we

[21] Unscheduled dates are identified by comparing scheduled and actual completion dates of TUDs. As expected, the proportion of TUDs completed on unscheduled dates is largest in wave 1 (the first wave of the LSAC and TUD, 43 %) and wave 4 (when the child completed the TUD for the first time, 47 %).

explore possibility (i) by excluding the list of the individual and household level explanatory variables from equation (1). The estimates from this modified model (reported in Appendix Table B10) are very similar to that from the baseline model, suggesting that confounding is unlikely to influence our results. These results therefore suggest little evidence of location selection in our data and weather conditions are genuinely exogenous in the children's time-use equations in our case. These findings also lend support to the identification strategy using cross-sectional data by Connolly (2008) and Graff Zivin and Neidell (2014).

5.5. Accounting for zeros in time allocation

While all children in our sample allocated non-zero time to sleeping or personal care each day, not all of them participated in some aggregated activities. Appendix Table B5 shows that, on time-use diary dates, the proportion of children did not undertake active, media or travel activities is relatively small, suggesting that linear models are appropriate in modelling the amount of time allocated to these activities. However, Appendix Table B5 also indicates that a large proportion (> 20 %) of children did not allocate any time to school and educational activities on the time-use diary dates. (This is not particularly surprising because, at very young ages, children are not eligible to participate in school.) We further check the robustness of our results to the mass of zeros observed for these activities by employing a two-part model which account for the mass of zeros (Cameron & Trivedi 2005).[22] The results from the two-part model (reported in Appendix Table B11) are very similar to the baseline results, suggesting that our results are not sensitive to the mass of zeros for some activities.

5.6. Using different functional forms of weather variables

Previously, we included weather variables as continuous in the regressions. In this section, we check the robustness of our results to different functional forms of weather variables that have been used elsewhere in the literature. In particular, we follow Graff Zivin and Neidell (2014) to include separate indicators for various groups of temperature in 2.5ºF bands, using 81.0ºF -83.5ºF (27.2ºC-28.6ºC) as the base, resulting all other temperature estimates are compared to this temperature band. We also follow Connolly (2008) to introduce a dummy variable indicating a rainy day with 0.1 inches of precipitation or more in the regressions. The

[22] Specifically, we separately estimated a probit model for the probability of observing a positive-versus-zero time use and, conditional on a positive time allocation, a linear model for the positive time use. We then calculated unconditional marginal effects for weather variables from these two-part models. We did not apply these models to the total time allocated to sleeping or personal care because these activities do not have mass zero issues. Using Tobit models which also accommodate the mass of zeros produces comparable results. Unreported results from a seemingly unrelated regression model to account for inter-correlation among activities are largely similar to the baseline estimates.

results from this experiment (reported in Appendix Table B12) confirm the well-defined non-linear relationships between temperature and the time allocated to active, media, travel or outdoor activities. We also observe that although the estimates for temperature bands at the higher end of the temperature distribution on active and outdoor activities are negative, they lack statistical power, possibly because the TUD dates are concentrated in non-summer months when high temperatures are not frequent. Similarly, the estimates of precipitation suggest that, on rainy days, children spend less time outdoors, mainly by reducing the time allocated to active pursuits and increasing the time to media.

Above, we examined the impact of daily maximum temperature because maximum temperatures are likely to be highly correlated with other daily temperature measures and hence may capture temperature exposure reasonably well. Furthermore, as demonstrated in Appendix Figure A4, most children sleep when minimum temperatures (which we also control for in regressions) usually occur, so including daily maximum temperature in regressions is expected to affect the time spent on activities rather than sleeping. As further checks of the sensitivity of our results, we conduct three experiments. First, we exclude minimum temperature and find our estimates are largely unchanged (results are reported in Appendix Table B13). Second, we use average daily temperature instead of daily maximum temperature and reach similar findings, although the temperature estimates are slightly smaller (see Appendix Table B14). Third, we include precipitation which is now calculated over a shorter time windows from 5:00 to 23:59 during the diary date in place of daily precipitation over the whole day (i.e. from 0:00 to 23:59). The results (represented in Appendix Table B15) show that although the estimates of daily maximum temperature are literally the same as observed in the baseline regressions, estimates of the newly derived precipitation are more pronounced in magnitude. This is expected because most of children undertake active, travel, media and outdoor activities within the 5:00-23:59 time window (see Appendix Figure A4) and precipitation outside this time window may not affect such activities. These results are also consistent with our earlier evidence of intra-day effects of temperature and precipitation on children's time allocation (see Sub-section 4.2).

5.7. The potential reporting errors by parents and children

Parents and children may report children's time use differently. Unfortunately, changes in the structure of TUDs used by parents and children do not allow us to directly investigate the potential differential reporting errors by them, including whether parents round up their reports more often than children do. This is because, as noted in Sub-section 2.1.2, while

parents' reports of children's activities are listed according to the 96 15-minute periods of each 24-hour block in the first three waves of data, children's self-reported activities are recorded in the form of an "activity episode" diary in waves 4 to 6. Furthermore, activities that the study child undertook during the time diary day are listed slightly differently across waves to reflect age-specific activities, making it hard to identify potential differentials in reporting errors by parents and children.

However, the potential disparity in parents' reports of children's time-use and children's self-reported time use, if any, is unlikely to change the weekday/weekend results that we documented above for three reasons. First, as described in Sub-section 2.2, parents' reports are available in the first three waves and the number of TUDs is distributed evenly by weekdays/weekends. Likewise, children's self-reported TUDs were completed on both weekends and weekdays in waves 4-6 and the number of TUDs is distributed equally by weekdays/weekends each wave. If we assume that reporting errors, if any, by either parents or children, is the same for weekdays and for weekends, such reporting errors should have similar impact on the estimation of weather on children's time allocation by weekdays/weekends. Second, while parents' perceptions about weather are associated with some characteristics of parents and children (as shown in Appendix Table B), our results on the impact of weather on both weekdays and weekends are robust to the exclusion of a rich list of characteristics of parents and children (as demonstrated in Appendix Table B10). If reporting errors are associated with some of the observed characteristics of parents or children, the stability of the results in specifications with and without such characteristics suggest that our weekday/weekend findings are not driven by such reporting errors. Third, as reported in Sub-section 5.4, FE results are largely similar to the pooled regression results. The similarity between FE and pooled regression results suggest that any reporting errors which may be associated with individual time invariant unobservable characteristics are not behind our findings of the differential weather effects by weekdays/weekends.

6. Heterogeneity

The main results show that children statistically significantly adjust their time allocated to active, media, travel and outdoor activities in response to weather conditions.[23] It may be that children with different characteristics respond differently to weather conditions. We investigate the heterogeneity of the effect by estimating equation (1) for two sub-populations,

[23] For brevity, we present heterogeneous analyses for these four grouped activities. We also conducted similar heterogeneous analyses for other grouped activities and found largely similar results as reported in Section 4. Results on other grouped activities are available upon request.

separated by each variable of a series of characteristics, including the child's health status (represented by having asthma)[24] and maternal employment status (unemployed or full-time employed).[25] Our *a priori* expectation is that unfavourable weather conditions will have a larger impact on sub-populations who are more sensitive to such weather conditions. For example, it is likely that children with asthma are more sensitive to extreme temperatures (i.e. too hot or too cold) because extreme temperatures are common asthma triggers (Beggs & Bambrick 2005).

We also consider whether the child lives in colder regions and whether the child was surveyed during winter months. We define colder regions as those with latitude in the lowest third[26] of all latitudes of postcode centroids observed in our main sample and warmer regions as those in the highest third. In our data, regions with a lower latitude (and hence are located further from the equator) have statistically significantly lower historical temperatures. It is possible that children in colder regions are more sensitive to warmer temperatures. Similarly, children surveyed during non-winter months are possibly less responsive to warmer temperatures because they are more accustomed to warmer temperatures. As such, heterogeneous analyses by seasons (or climate regions) also provide an effective test for short-run (or longer-run) adaptation to weather conditions (Graff Zivin & Neidell 2014).

Appendix Table B17 - Panel A indicates that temperature has a much stronger impact for children with asthma as the estimates are usually more statistically significant or of a higher magnitude for them. In particular, the estimates of first-order term for temperature on active (on weekends) and media (on weekends) activities are twice as large for children with asthma. Furthermore, the estimates of temperature on media (on weekdays) and travel (on weekends) are only statistically significant for children with asthma. Consistent with our earlier finding of a stronger temperature impact on weekends, the differences in temperature impact by the child's asthma morbidity are also more pronounced for activities undertaken on weekends. The finding that temperature has more noticeable impacts for children with asthma is consistent with our early prediction that they are more sensitive to extreme temperatures

[24] The child's asthma condition is constructed using responses to the question "Has a doctor ever told you that child has asthma?", which is asked in all waves except wave 1 for B cohort. About a quarter of children in our sample are reported having asthma.

[25] We have also experimented with other characteristics such as the child's gender, birth cohort (which represents child ages), maternal education, maternal nativity, family income (in the bottom or top quarter of the income distribution) and housing conditions (as presented by the number of rooms per person). The unreported results show no discernible differential weather impacts by such characteristics or the heterogeneous impacts that can be easily explained.

[26] We use the tertile to ensure that the size of each sub-sample is relatively comparable and sufficiently large to achieve reliable estimates. Similarly, we only define two sub-groups by winter seasons (from June to August) to ensure that the size of each sub-sample is sufficiently large to get precise estimates.

(Beggs & Bambrick 2005). By contrast, precipitation has a statistically significant impact on time allocated to active, media (weekends only), travel (weekdays only) and outdoor activities undertaken by children without asthma morbidity only. The finding that precipitation does not statistically significantly affect the time that children with asthma allocate to the above activities is in line with the ideas that rainfall clears the air from pollen or pollution, thus reducing the risk of asthma (Neidell 2004; Beggs & Bambrick 2005).[27]

We further investigate whether the heterogenous weather effects by the child's asthma condition found above are associated with temperate/precipitation or air pollution. To do this, we explore the associations between air quality indicators and weather measures by applying a FE regression of each of hourly air quality indicators on various contemporary weather conditions.[28] Available data show that hourly air pollutions, as measured by particulate matters such as PM10 or PM2.5 and oxides of nitrogen (NO2), nephelometer (NEPH), sulphur dioxide (SO2) or carbon monoxide (CO), are highly correlated with hourly weather parameters, especially precipitation and temperature (see Appendix Table B16). In particular, consistent with evidence from previous studies of the washout effect on air pollutants (Martin 1984; Russell & Dennis 2000; Yoo *et al.* 2014), our results show that the correlations between precipitation and all included air pollution indicators are negative and statistically significant. The negative correlations between air pollution and precipitation when observed with evidence that poor air quality increases the child hospitalizations for asthma (Neidell 2004) indicate that air pollution is one potential mechanism behind our finding. Furthermore, the associations between temperature and particulate matters (i.e., PM10 and PM2.5) are highly statistically significant (at the 1% level) and non-linear, indicating that air pollution decreases with temperature before starting to increase after some point. This non-linear relationship between temperature and pollution is consistent with our finding and similar evidence from the literature that children with asthma are more sensitive to extreme temperatures (Beggs & Bambrick 2005). Overall, the results suggest that both extreme temperatures and air pollution are plausible factors explaining our finding of the differential impact of weather on time allocation of children with and without asthma.

[27] Consistent with the heterogeneous weather impact by the child's asthma status, unreported results show that temperature has a statistically significant (at the 1 % level) and an inverted U-shaped impact on sleeping time (weekdays only) of children with asthma only. By contrast, daily precipitation has a statistically significant (at the 1 % level) and positive impact on sleeping time (weekdays only) of children without asthma only.

[28] Unfortunately, we do not have access to historical local air pollution data that would allow us to include them in addition to weather indicators in the regression to directly identify whether the effects we find are associated with temperate/precipitation or air pollution. We thank an anonymous reviewer for comments which have led to these additional results.

The estimates by the mother's employment status (i.e. full-time versus unemployed – see Appendix Table B17– Panel B) also suggest some heterogeneous effects of weather. Again, the differential weather impact appears to vary by weekdays and weekends. In particular, on weekdays, temperature tends to have a stronger impact on time allocated to active, media and outdoor activities undertaken by children of unemployed mothers because the estimates are more statistically significant for them. Similarly, also on weekdays, precipitation has a greater effect on time spent on travel and outdoor activities by children of unemployed mothers. On weekends, temperature has a greater (smaller) impact on active and outdoor (media) activities by children of full-time working mothers. Furthermore, also on weekends, precipitation has a statistically significant effect on the time allocated to media and outdoor activates undertaken by children of unemployed mothers only. Our finding of a greater weather impact for children of unemployed mothers is consistent with the view that unemployed mothers (and hence their children) are more flexible in terms of time, especially on weekdays.

Appendix Table B18 – Panel A indicates that children's time allocation to weekend outdoor activities is much more sensitive to temperature in winter months as the temperature estimates are statistically significantly higher in winter months than in non-winter months. The greater impacts of temperature in winter months viewed with one of our earlier findings that the temperature impact is mainly concentrated at the lower end of the temperature distribution (Sub-section 5.6) suggest that children surveyed during winter months are more responsive to temperature increases than those surveyed in warmer months. This pattern is consistent with the hypothesis of short-run acclimatization outlined above. By contrast, children are more responsive to rain in non-winter months, particularly for active, media and outdoor activities undertaken on weekends, as the estimates of precipitation are more statistically significant or of a higher magnitude for activities undertaken during non-winter seasons. The greater impact of precipitation in non-winter months can be explained by the fact that there is statistically significant more rain in non-winter months than in winter months in Australia. Again, differences in temperature and precipitation impact by seasons appear to be more noticeable on weekends, a pattern which is highly consistent with predictions that children are more flexible on weekends.

Turning to the estimates of temperature by climate regions (Appendix Table B18 – Panel B), we continue to observe evidence of longer-run adjustments as temperature has a discernibly-greater impact (in terms of the statistical significance level and magnitude of the estimates)

on the time spent on outdoor (weekends only), media (weekends only) and active (weekdays only) pursuits by children in colder regions. Our finding that the responses to heat are larger in colder places echoes recent findings in the literature (Barreca *et al.* 2016; Behrer & Park 2017; Heutel *et al.* 2017). However, there is no clear pattern in the impacts of precipitation, which is not statistically different between the two defined climate regions, by climate regions. In particular, while precipitation has more noticeable effects on media (weekends only) and outdoor (weekends only) activities by children in colder regions, it has a greater impact on active activities (weekdays only) of children in warmer regions.

7. Discussion

Above, we found that children's time spent at school is not affected by contemporaneous unfavourable weather conditions.[29] This finding is mostly likely consistent with the idea that institutional constraints associated with school schedules may limit children's ability to skip school due to bad weather.[30] The results also indicate that children's educational time outside school is not responsive to adverse weather conditions, probably due to the indoor nature of this activity. The insignificant weather effects on schooling and own educational time when viewed with evidence that time spent on educational activities is the most productive input for cognitive skill development (Fiorini & Keane 2014; Nguyen *et al.* 2019) suggest that unfavourable weather conditions may not diminish children's subsequent cognitive performance via the educational or schooling time channel.

[29] To our best knowledge, this is the first evidence on the impact of weather on school attendance (Graff Zivin & Shrader 2016). Our finding of an insignificant link between extreme weather conditions and school attendance is not directly comparable to some evidence of a significant impact of natural disasters on school drop-outs of children in developing countries (Kousky 2016) for at least two reasons. First, we investigate the contemporary impact of weather elements while other studies focus on delayed effects of climate-related shocks (e.g., cyclones, flash floods, or drought), which are much more damaging than our weather indicators. Second, the differences in country contexts, i.e., resources are more limited in developing countries than in a developed country like Australia, also help explain the differences in our findings.

[30] Unfortunately, we do not have access to historical air conditioning data at a local level (e.g., at the school level) which would enable us to directly examine the role of air conditioning in protecting students from extreme temperatures. However, the availability of air-conditioning at school, which has been shown to offset the negative impact of hot temperature on performance of students during exams in the US (Graff Zivin *et al.* 2018; Park 2018; Goodman *et al.* 2019), is unlikely to explain our findings for three reasons. First, in Australia, students usually have two-month summer holidays when the temperature typically peaks. This school schedule thus limits the role of air-conditioning in protecting students from the extreme heat. Furthermore, our data do not include many hot days due to the fact that most of TUDs were completed during non-summer months and this limits our ability to make reference about the impact of very high temperatures on school attendance. Second, our postcode-time fixed effects model (1) captures secular changes in air-conditioning penetration over the time span of our data. Third and most plausibly, our findings are not sensitive in a child FE model which controls for the child time-invariant unobservable factors, including air-conditioning status of the child's school (see Sub-section 5.4).

However, the results should not be interpreted as extreme weather conditions do not directly influence children's cognitive performance. This is mainly because our data do not have information about the quality of the time spent on each activity as well as the actual activities children do at school, limiting our ability to draw the inference about the direct and immediate impact of weather on students' learning or productivity outcomes. It is possible that children still go to school on days with unfavourable weather conditions but the activities they do at school may be changed (e.g., by shifting from outdoors to indoors) or their performance may be negatively affected. This projection is consistent with growing evidence that high temperature on the day of the test diminishes students' test scores (Graff Zivin *et al.* 2018; Park 2018; Goodman *et al.* 2019; Roach & Whitney 2019).[31]

Our findings of the negative impacts of adverse weather conditions on children's physically active time coupling with large evidence that physically active activities improve child health and academic performance (Janssen & LeBlanc 2010; Donnelly *et al.* 2016) suggest that extreme weather conditions may diminish children's development and long-term achievements through their effects on children's time allocation (Graff Zivin & Shrader 2016). The results also indicate policies increasing access to indoor active activities are a step in the right direction, in terms of getting children to participate in physically active activities on dates with unfavourable weather conditions.[32] Furthermore, our findings of the differential weather impacts suggest that such policies would be more beneficial to children who are found to be affected more by unfavourable weather conditions, including children with asthma.

8. Conclusion

This paper sheds new light on how weather influences children' and adolescents' time allocations. Our results show that unfavourable weather conditions, as represented by cold or hot temperature or rain, cause children to shift their activities from outdoors to indoors, mainly by reducing the time allocated to active or travel activities and hence increasing the time allocated to media activities. We additionally uncover that the impact of weather is more

[31] It is also in line with related evidence of the negative impact of indoor air pollution on students' test scores (Stafford 2015) or workers' productivity (Graff Zivin & Neidell 2012; Chang *et al.* 2016; Heyes & Saberian 2018).

[32] Given inconclusive evidence on the impact of media time on child development in the current literature (DellaVigna & La Ferrara 2015; Bulman & Fairlie 2016), it is unclear how the changes in children's media time due to weather conditions found in this paper would affect children's development outcomes. Similarly, large differences, in terms of the type of activity measured, the type of child development outcomes examined and the magnitude, on the effects of time allocation on child development from currently available literature (Janssen & LeBlanc 2010; Donnelly *et al.* 2016) limit our ability to calculate back-of-the-envelope figures on the potential impact of extreme weather conditions on child development outcomes.

pronounced on weekends than weekdays, a novel finding which is consistent with the notion that children may have more freedom to adjust to weather conditions on weekends.

Our results also reveal separate sub-groups of the population appear to allocate their time differently in response to weather conditions. For example, as compared to children without asthma, those with asthma are significantly more responsive to temperature and less affected by precipitation. Furthermore, the impacts of temperature vary greatly by regions, with colder regions showing the greater impact of temperature on time allocations. Likewise, children surveyed in colder months are more sensitive to warmer temperatures. These differential temperature impacts by seasons (or climate regions) can be viewed as supportive of the short-run (or longer-run) adaptation to weather conditions. Our analyses also provide other suggestive evidence for short-run adaptation to weather conditions because children tend to shift activities to more favourable times of the day.

While this study offers insight into the role of weather on children's time allocation, future research could investigate several important questions. For example, it would be useful to study the long-term impact of weather on children's time allocation. It would also be interesting to examine the long-term effects of children's time allocation on their development outcomes. Answers to these questions would offer valuable insight into the effects of weather conditions, through their effects on children's time allocation, on children's development and long-term achievements.

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Table 1. Summary statistics

	Weekday (N = 22944)		Weekend (N = 22403)		All (N = 45347)	
	Mean	SD	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Sleep (minutes per day)	645.06	135.72	657.36	129.65	651.14	132.90
Personal care (minutes per day)	334.76	168.97	337.75	148.48	336.24	159.18
School (minutes per day)	196.49	188.39	12.15	60.94	105.42	168.18
Educational (minutes per day)	108.18	130.33	97.14	114.10	102.72	122.70
Active (minutes per day)	136.85	127.87	225.48	159.85	180.64	151.19
Media (minutes per day)	114.00	104.52	167.73	137.56	140.54	124.89
Travel (minutes per day)	79.80	76.18	89.26	95.25	84.47	86.26
Outdoor (minutes per day)	103.78	116.03	171.54	165.41	137.25	146.55
Maximum temperature (°F)	66.97	9.89	66.57	10.07	66.77	9.98
Minimum temperature (°F)	48.21	9.04	48.01	9.18	48.11	9.11
Precipitation (inches)	0.06	0.21	0.06	0.20	0.06	0.20
Maximum relative humidity (%)	90.36	9.04	90.14	9.17	90.25	9.10
Minimum relative humidity (%)	47.34	16.39	47.58	16.65	47.46	16.52
Maximum wind speed (miles per hour)	24.14	8.91	24.29	8.81	24.21	8.86
Minimum wind speed (miles per hour)	3.51	4.45	3.65	4.55	3.57	4.50
Maximum wind direction (° to the north)	312.50	57.22	311.04	58.34	311.78	57.78
Minimum wind direction (° to the north)	43.87	66.35	45.28	67.27	44.57	66.81
Daylight (hours)	10.93	1.05	10.89	1.02	10.91	1.03
Child age (months)	78.89	50.43	80.19	48.03	79.53	49.26
Male [(a)]	0.51	0.50	0.51	0.50	0.51	0.50
Aboriginal [(a)]	0.02	0.15	0.02	0.15	0.02	0.15
Child health	1.59	0.76	1.59	0.76	1.59	0.76
Low birth weight [(a)]	0.06	0.24	0.06	0.24	0.06	0.24
Mother age (years)	37.16	6.52	37.39	6.33	37.28	6.43
Mother education: Certificate/Diploma [(a)]	0.26	0.44	0.25	0.43	0.25	0.43
Mother education: Bachelor or higher [(a)]	0.39	0.49	0.39	0.49	0.39	0.49
Maternal general health	2.25	0.88	2.24	0.87	2.25	0.87
Mother employed part time [(a)]	0.48	0.50	0.49	0.50	0.48	0.50
Mother employed full time [(a)]	0.20	0.40	0.20	0.40	0.20	0.40
Mother ESB migrant [(a)]	0.09	0.29	0.09	0.29	0.09	0.29
Mother NESB migrant [(a)]	0.11	0.32	0.11	0.32	0.11	0.32
Number of household members	4.40	1.14	4.41	1.11	4.41	1.13
Living with both parent [(a)]	0.85	0.35	0.87	0.34	0.86	0.35
Weekly family income (AUS$ 1,000)	1.92	1.46	1.99	1.56	1.96	1.51

Notes: This table reports summary statistics (means in odd columns and standard deviations (SD) in even columns) of main variables using individual level data from the Longitudinal Survey of Australian Children (LSAC) – Release 6 and weather data from the Australian Bureau of Meteorology. [(a)] indicates dummy variables.

Table 2. Weather conditions and children's time allocation

	Bed		Personal care		School		Education	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	1.62	1.47	-1.64	-2.42*	0.36	0.26	1.48	1.17
	[1.10]	[1.02]	[1.49]	[1.34]	[1.34]	[0.55]	[1.13]	[1.01]
Max temperature squared	-0.01*	-0.01	0.01	0.01	-0.00	-0.00	-0.01	-0.01
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]
Min temperature (°F)	-0.13	-0.27	-0.17	0.39	0.12	-0.00	0.22	-0.38*
	[0.21]	[0.21]	[0.30]	[0.27]	[0.27]	[0.11]	[0.22]	[0.21]
Precipitation (inches)	6.30**	1.07	2.66	4.90	-1.98	-3.78**	2.15	-0.85
	[3.01]	[3.95]	[5.60]	[5.81]	[5.37]	[1.63]	[5.38]	[3.92]
Max humidity (%)	0.03	-0.25**	0.16	0.19	0.37**	0.10	0.11	0.14
	[0.11]	[0.12]	[0.17]	[0.15]	[0.16]	[0.06]	[0.13]	[0.11]
Min humidity (%)	-0.20**	0.12	0.15	-0.08	0.02	-0.05	0.03	-0.00
	[0.10]	[0.10]	[0.14]	[0.12]	[0.13]	[0.05]	[0.10]	[0.09]
Max wind speed (mph)	0.03	0.25*	0.16	0.14	0.13	0.04	-0.04	-0.04
	[0.13]	[0.14]	[0.19]	[0.18]	[0.19]	[0.07]	[0.14]	[0.13]
Min wind speed (mph)	0.20	-0.39	0.31	0.38	-0.21	0.15	-0.47	0.26
	[0.28]	[0.31]	[0.42]	[0.38]	[0.40]	[0.16]	[0.31]	[0.28]
Max wind direction	-0.02	-0.01	-0.00	0.03*	-0.01	-0.01	0.01	-0.01
	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.01	0.01	-0.03	-0.01	-0.03	0.01	0.03*	0.00
	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]
Daylight (hours)	-5.85**	-2.46	-1.52	-2.05	8.70***	1.36	2.68	1.51
	[2.37]	[2.11]	[2.88]	[2.55]	[3.12]	[1.19]	[2.26]	[1.89]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.338	0.226	0.128	0.086	0.360	0.097	0.133	0.161
Sample mean	645.1	657.4	334.8	337.7	196.5	12.15	108.2	97.14

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Table 2. Weather conditions and children's time allocation (continued)

	Active		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(9)	(10)	(13)	(14)	(15)	(16)	(17)	(18)
Max temperature (°F)	4.06***	4.79***	-1.66	-4.22***	0.31	1.80**	3.30***	10.48***
	[1.05]	[1.31]	[1.14]	[1.13]	[0.68]	[0.80]	[0.92]	[1.31]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.01***	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.41*	-0.37	0.27	0.03	-0.16	-0.32*	-0.28	-0.75**
	[0.21]	[0.29]	[0.19]	[0.23]	[0.14]	[0.17]	[0.20]	[0.30]
Precipitation (inches)	-13.29***	-13.25**	1.50	17.02***	-7.69***	-1.38	-22.90***	-24.52***
	[3.51]	[6.09]	[3.23]	[5.02]	[2.10]	[4.83]	[3.22]	[7.14]
Max humidity (%)	-0.03	-0.01	0.10	-0.15	-0.03	0.01	-0.19*	-0.26
	[0.12]	[0.15]	[0.11]	[0.12]	[0.08]	[0.10]	[0.11]	[0.16]
Min humidity (%)	0.07	-0.06	-0.17*	0.20*	0.05	-0.04	0.13	-0.14
	[0.10]	[0.13]	[0.09]	[0.11]	[0.07]	[0.08]	[0.09]	[0.13]
Max wind speed (mph)	-0.04	-0.26	-0.17	-0.10	0.07	-0.17	-0.23*	-0.63***
	[0.13]	[0.18]	[0.12]	[0.14]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.49*	-0.22	0.47*	0.21	-0.08	0.38	0.21	-0.88**
	[0.29]	[0.39]	[0.27]	[0.31]	[0.19]	[0.23]	[0.28]	[0.39]
Max wind direction	-0.01	-0.01	0.02	-0.00	-0.01	-0.00	-0.02	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.01	0.01	0.01	0.01	-0.01	-0.02*	-0.01	0.01
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-0.90	2.24	0.48	-2.42	-2.51**	3.09*	0.51	7.29**
	[2.10]	[2.64]	[1.92]	[2.01]	[1.24]	[1.69]	[2.07]	[2.91]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.195	0.145	0.088	0.247	0.074	0.068	0.100	0.133
Sample mean	136.8	225.5	114	167.7	79.80	89.26	103.8	171.5

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Table 3. Inter-day substitution – Impacts of weather conditions over the previous 6 days

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Current max temperature (°F)	3.30***	5.15***	-2.43*	-4.29***	0.60	1.86*	2.50**	9.82***
	[1.28]	[1.71]	[1.35]	[1.44]	[0.86]	[1.05]	[1.26]	[1.73]
Current max temperature sq.	-0.02**	-0.03***	0.01	0.03***	-0.00	-0.02**	-0.01	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Current precipitation (inches)	-9.44**	-14.34**	0.41	13.97**	-5.90**	1.74	-16.88***	-19.47**
	[4.45]	[7.12]	[4.03]	[5.62]	[2.72]	[5.29]	[3.97]	[8.20]
Lagged max temperature (°F)	0.89	-0.65	0.71	-0.15	-0.73	-0.04	1.34	1.33
	[1.37]	[1.94]	[1.26]	[1.59]	[0.90]	[1.30]	[1.42]	[2.01]
Lagged max temperature sq.	-0.01	0.01	-0.00	0.00	0.00	0.00	-0.01	-0.01
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Lagged precipitation (inches)	-17.90	2.34	0.36	10.36	-7.01	-11.42*	-27.08***	-22.08
	[10.96]	[13.39]	[8.96]	[8.40]	[7.15]	[6.85]	[9.79]	[15.70]
Observations	22,934	22,393	22,934	22,393	22,934	22,393	22,934	22,393
R-squared	0.196	0.145	0.089	0.247	0.074	0.068	0.100	0.133

Notes: This table reports regression coefficients of the impact of various (both contemporaneous and lagged) weather conditions on children's time allocation based on equation (1). Lagged weather conditions are defined over the previous 6 days. The list of covariates includes other (both contemporaneous and lagged) weather variables such as minimum daily temperature, humidity, wind speed, wind direction and (contemporaneous) daylight. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

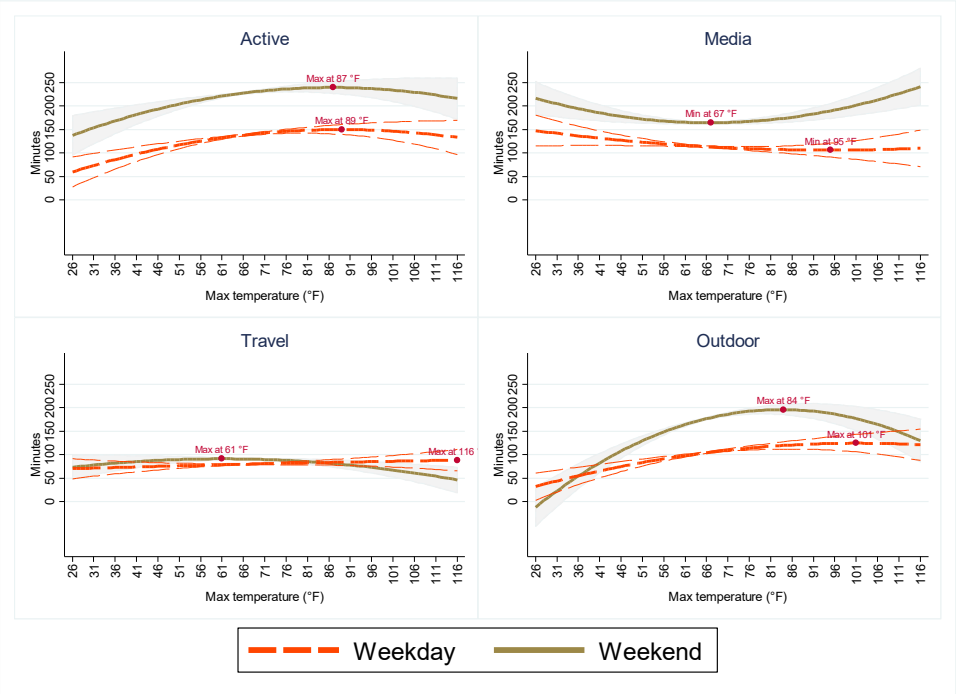
Table 4. Intra-day substitution – Impacts of weather conditions by time of day

	Weekday		Weekend		Weekday		Weekend	
	Twilight	Daylight	Twilight	Daylight	Twilight	Daylight	Twilight	Daylight
	Active activity				Media			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	0.92**	2.92***	0.39	4.51***	0.07	-1.09*	-0.19	-4.09***
	[0.40]	[0.78]	[0.46]	[0.97]	[0.49]	[0.58]	[0.48]	[0.69]
Max temperature sq.	-0.00	-0.02***	-0.00	-0.03***	-0.00	0.01	0.00	0.03***
	[0.00]	[0.01]	[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
Precipitation (inches)	-6.42***	-6.59**	-1.88	-13.38***	-0.10	2.74	1.24	11.95***
	[1.36]	[2.82]	[1.98]	[4.44]	[1.57]	[1.98]	[1.87]	[3.31]
Observations	22,944	22,944	22,403	22,403	22,944	22,944	22,403	22,403
Sample mean (minutes)	41.80	87.51	45.69	166.29	52.40	40.10	62.36	76.07
	Travel				Outdoor			
Max temperature (°F)	0.18	0.24	0.55**	1.11*	0.32	3.42***	0.63	8.79***
	[0.25]	[0.53]	[0.26]	[0.64]	[0.32]	[0.72]	[0.39]	[0.99]
Max temperature sq.	-0.00	-0.00	-0.00**	-0.01**	-0.00	-0.02***	-0.00	-0.05***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]	[0.01]
Precipitation (inches)	-1.61*	-5.52***	-1.64	0.51	-5.87***	-13.49***	-4.44**	-23.42***
	[0.84]	[1.76]	[1.29]	[3.61]	[0.97]	[2.48]	[2.00]	[4.65]
Observations	22,944	22,944	22,403	22,403	22,944	22,944	22,403	22,403
Sample mean (minutes)	24.70	52.25	16.02	69.21	24.37	72.88	26.81	132.28

Notes: This table reports the impact of temperature and precipitation on children's time allocation by time of day. Results are obtained from equation (1). Twilight is defined as the time before 2 hours after 7:00 and after 2 hours before 19:00. Daylight includes the time between 9:00 and 17:00. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Weather variables such as daily minimum temperature, humidity, wind speed, wind direction and daylight are included. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

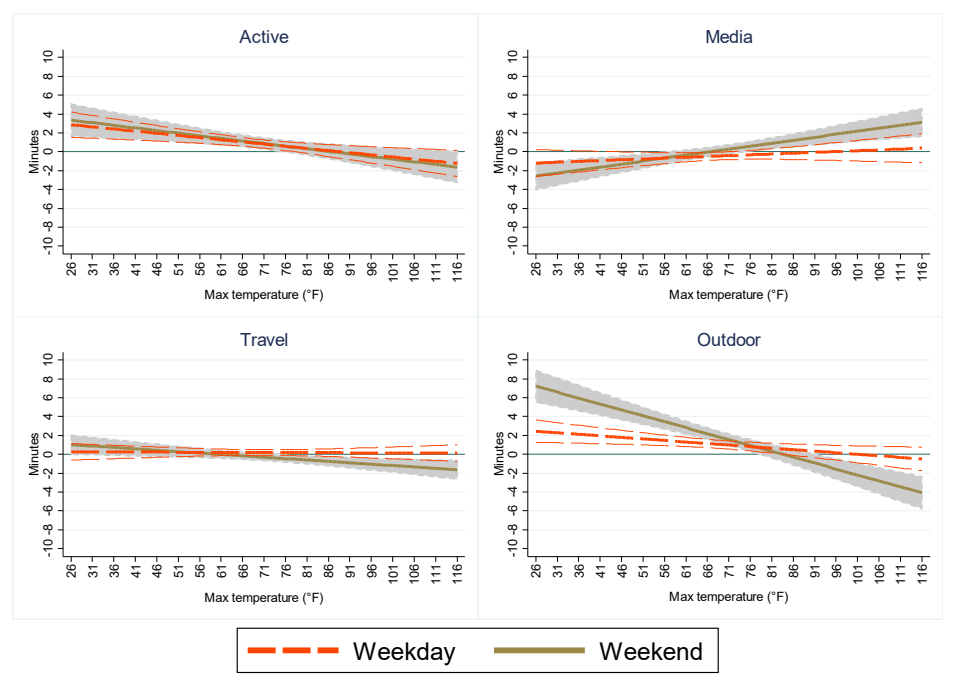
Figure 1. Relationship between temperature and time allocation

Panel A. Predicted time allocation by daily maximum temperatures



Notes: This figure plots the predicted daily time (in minutes) allocated to various grouped activities by daily maximum temperatures. Thick solid (long dotted) line displays the predicted time allocation during weekends (weekdays) based on equation (1). The 95% confidence interval is shaded in grey for weekends or between thin long dotted lines for weekdays. Full regression results are presented in Table 2 and Appendix Table B3.

Panel B. Marginal effects of daily maximum temperature on children's time allocation



Notes: This figure plots the marginal effects of daily maximum temperature on time allocated to various grouped activities. Other notes: See panel A.

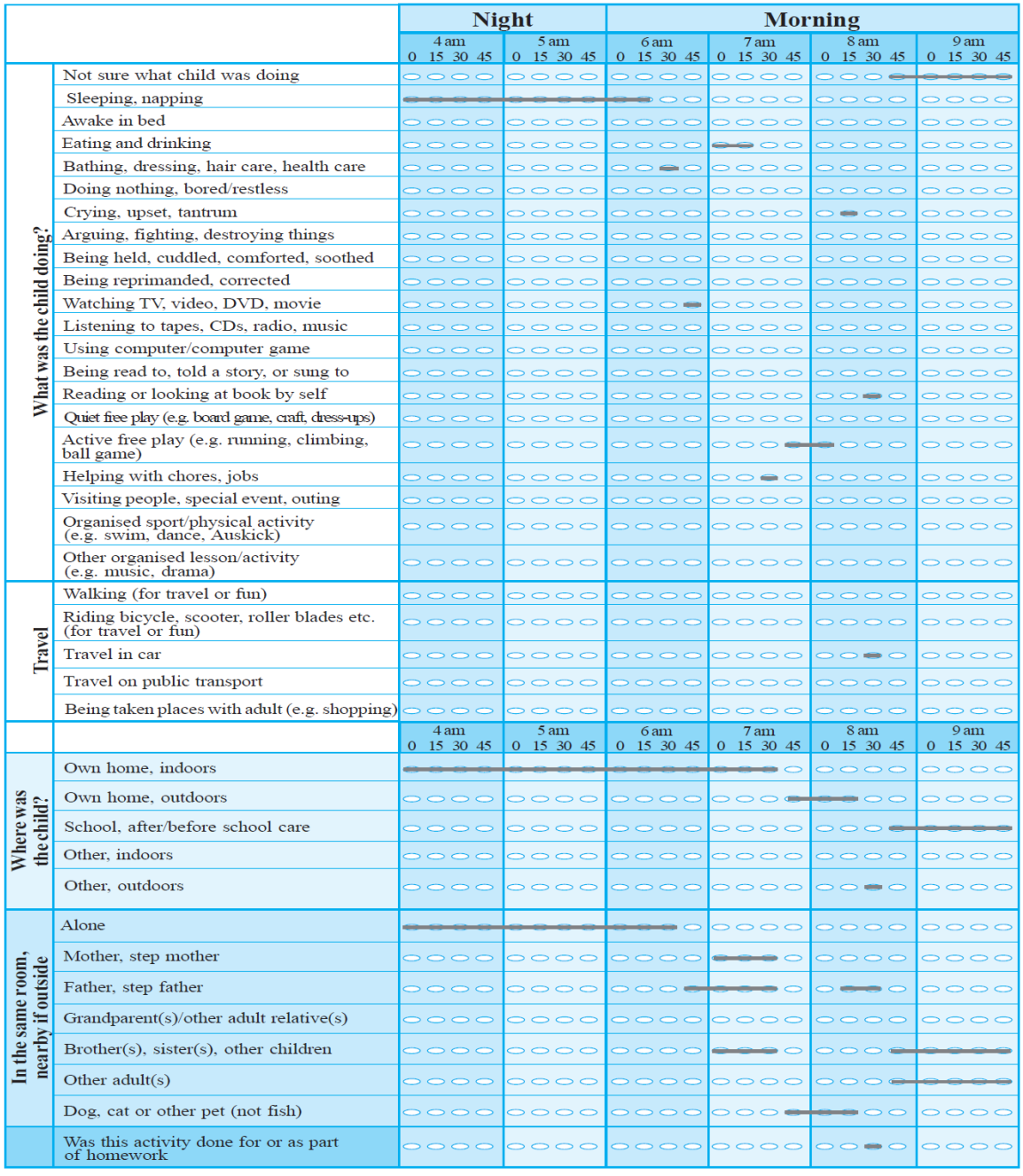
Online Appendix A: Data description

Appendix Figure A1. Sample of Time-use Diary and activity codes – wave 2

EXAMPLE

Below is an example of how the diary would be filled in for a child's morning.

Joshua woke at 6.30am and dressed himself. He then watched the morning news with his father. At 7.00am he had breakfast with his parents and baby brother. After breakfast he helped his mother clear the breakfast dishes from the table and at 7:45am went outside to play with the family dog. At 8.15am his father went outside to tell Joshua it was time to leave for school. Joshua became upset because he didn't want to stop playing with the dog. His father calmed him down and they left home at 8.30am to drive to school. During the drive to school Joshua read out loud to his father from a book he had brought home from school the previous day. His father dropped him off at school ten minutes later and gave him a hug goodbye before going on to work.



Appendix Figure A2. Sample of Time-use Diary - wave 5

Source: Corey et al. (2014).

Appendix Figure A3. Sample of activity codes – Time-use Diary wave 5

Work	**Non-Active Activities**
00. Retailing (including fast food)	50. Filling out the diary
01. Pamphlet delivering	51. Private music lessons/practice, academic tutoring
02. Umpiring/refereeing	52. Listening to music, Playing musical instruments or singing for leisure
03. Car washing	53. Reading or being read to for leisure
04. Gardening / lawn mowing	54. Unstructured non-active play
05. Babysitting	55. Non-active club activities
06. Animal care	56. Doing nothing
07. Working in a family business or farm	57. Sleeping/napping (not end of the day bed-time)
08. Work nec.	58. Doing homework (not via electronic devices)
09. Volunteering	59. Non-active activities nec.
Eating/Drinking	**Electronic Device Use**
10. Eating/drinking	60. Doing homework
	61. Playing games
Personal Care/ Medical/Health Care	62. Watching TV programs or movies/videos
20. Cleaning teeth	63. Spending time on social networking sites
21. Showering/bathing	64. Downloading/posting media (e.g. music, videos, applications)
22. Getting dressed / getting ready	65. Internet shopping
23. Personal care nec.	66. General Internet browsing (excluding homework)
24. Doctor	67. Creating/maintaining websites (excluding social networking profile)
25. Dentist	68. General application use (e.g. Microsoft Office; excluding homework)
26. Physiotherapist / Chiropractor	69. Electronic device use nec.
27. Medical/Health care nec.	
Chores	**School Lessons**
30. Cleaning/tidying	70. School lessons
31. Laundry/clothes care	
32. Food/drink preparation	**Communication**
33. Food/drink clean up	80. Talking face-to-face (in person not via electronic devices)
34. Gardening / lawn mowing	81. Talking on a landline phone (not video chat)
35. Animal care (excluding active play)	82. Talking on a mobile phone (not video chat)
36. Home maintenance	83. Video chatting (e.g. Skype)
37. Taking care of siblings	84. Texting/emailing
38. Chores nec.	85. Online chatting / Instant messaging
	86. Non-verbal interaction (e.g. cuddles)
Active Activities	87. Communication nec.
40. Organised team sports and training	
41. Organised individual sport and training	**Travel**
42. Unstructured active play	90. By foot
43. Walking pets / playing with pets	91. By bike, scooter, skateboard etc.
44. Active club activities	92. By private motor vehicle/bike
45. Shopping	93. By public/chartered transport such as bus, taxi or aeroplane
46. Going out to a concert, play, museum, art gallery, community or school event , an amusement park etc.	94. Travel nec.
47. Religious activities / ritual ceremonies	
48. Attending live sporting events	**Others**
49. Active activities nec.	99. Others

Source: Corey et al. (2014).

Appendix Table A1. Coding rules for activities by B cohort children

Grouping	Wave 1	Wave 2	Wave 3	Wave 6
Sleep	Sleeping, napping	Sleeping, napping	Sleeping, napping	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")
Personal care	Awake in bed / cot; Looking around, doing nothing; Bathe / nappy change, dress / hair care; Breastfeeding; Other eating, drinking, being fed; Crying, upset; Destroy things, create mess; Held, cuddled, comforted, soothed; Not sure what child was doing	Awake in bed; Eating, drinking, being fed; Bathing, dressing, hair care, health care; Doing nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting; Destroy things, create mess; Being reprimanded; Being held, cuddled, comforted, soothed; Quiet free play; Being taught to do chores; Not sure what child was doing;	Awake in bed; Eating, drinking, being fed; Bathing, dressing, hair care, health care; Doing nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting; destroying things, creating mess; Being reprimanded; Being held, comforted, soothed; Quiet free play; Being taught to do chores; Not sure what child was doing	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec.; Doctor; Dentist/Orthodontist; Physiotherapist / Chiropractor; Medical/Health care; Personal care/Medical/Health Care nec.; Listening to music; Playing musical instruments or singing for leisure; Chess, card, paper and board games / crosswords; Games of chance / gambling; Hobbies, collections; Handwork crafts (excl. clothes making); Arts; Unstructured non-active play nec; Clubs; Religious groups; Doing nothing; Non-active activities nec.; Talking face-to-face; Talking on a landline phone; Non-verbal interaction; Negative face-to-face communication; Communication nec.; Illegal activities; Filling out the diary; Other; Retailing; Hospitality (including fast food); Clerical/office; Labourers and related workers; Gardening / lawn mowing; Babysitting; Apprenticeships/trades persons; Working in a family business or farm; Work Other; Umpiring (work); Car washing (work); Animal care (work); Volunteering (work); Cleaning/tidying; Laundry/clothes care; Clothes making; Food/drink preparation; Food/drink clean up; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Animal care; Home maintenance; Design/Home Improvement; Heat/water/power upkeep; Car/boat/bike care; Selling/disposing of household assets; Rubbish/Recycling; Packing; Household management Other; Taking care of siblings (chores); Chores nec; Uncodeable activity
School	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "Day care centre / playgroup" to the question "where was the child?"	School lessons, excluding Recess and Lunch

Grouping	Wave 1	Wave 2	Wave 3	Wave 6
Education	Read a story, talked / sung to, sing / talk; Colour / draw, look at book, puzzles; Organised activities / playgroup	Read a story, told a story, sung to; Colour/draw, look at book, educational game; Organised lessons/activities	Read a story, talk/sing, talked/sung to; drawing/colouring, looking at book, etc.; organised lessons/activity	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework (electronic device); Attend courses (excluding school /university)
Active	Crawl, climb, swing arms or legs; Other play, other activities; Visiting people, special event, party	Active free play; Visiting people, special event, party; Walking; Ride bicycle/trike	Active free play; visiting people, special event, outing; walking; travel in pusher/bicycle seat; ride bicycle, trike, etc.	Archery / Shooting sports; Athletics / Gymnastics; Fitness / Gym / Exercise; Ball Sports; Martial arts / Dancing; Motor Sports / Roller Sports / Cycling; Water/Ice/Snow Sports; Organised team sports and training other; Archery / Shooting sports (individual); Athletics / Gymnastics (individual); Fitness / Gym / Exercise (individual); Martial arts / Dancing (individual); Motor Sports / Roller Sports / Cycling (individual); Ball Sports (individual); Water/Ice/Snow Sports (individual); Organised individual sport and training other; Archery / Shooting sports (unstructured); Athletics / Gymnastics (unstructured); Fitness / Gym / Exercise (unstructured); Ball Sports (unstructured); Martial arts / Dancing (unstructured); Motor Sports / Roller Sports / Cycling (unstructured); Water/Ice/Snow Sports (unstructured); Unstructured active play Other; Walking pets/playing with pets; Active club activities; Shopping; Shopping; Purchasing consumer goods; Purchasing durable goods; Window shopping; Purchasing repair services; Purchasing administrative services; Purchasing personal care services; Purchasing other services; Attendance at movies / cinema; Attendance at concert/theatre; Attendance at museum / exhibition / art gallery; Attendance at zoo / animal park / botanic garden; Attendance at other mass events; Going out nec; Religious practice; Weddings, funerals, rites of passage; Religious activities / ritual ceremonies nec; Attending live sporting events; Active activities nec
Media	Watching TV, video or DVD; Listening to tapes, CD's, radio, music	Watching TV, video, DVD, movie; Listening to tapes, CDs, radio, music; Using computer, computer game	Watching TV, video, DVD, movie; listening to tapes, CDs, radio, music; using computer, computer game	Playing games (electronic device); Playing games (Electronic device) nfd; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media; Internet shopping; General Internet browsing; Creating/maintaining websites; General application use; Electronic device use nec.; Talking on a mobile phone; Video chatting; Texting/emailing; Online chatting / Instant messaging

Grouping	Wave 1	Wave 2	Wave 3	Wave 6
Travel	Taken places with adult (e.g. shopping); Taken out in pram or bicycle seat; Travel in car / other household vehicle; Travel on public transport, ferry, plane	Travel in car; Travel in a pusher/bicycle seat; Travel on public transport; Taken places with adult (e.g. Shopping)	Travel in car; travel on public transport; taken places with adult	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport; Travel nec.
Outdoor	Response "Other, outdoors" to the question "where was the child?"	Responses "Own home, outdoors" or "Other, outdoors" to the question "where was the child?"	Responses "Own home, outdoors" or "Other, outdoors" to the question "where was the child?"	Reponses "Yes" or "Both" to the question "Was the child outside?", plus Gardening / lawn mowing; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Travel by foot; Travel by bike, scooter, skateboard etc.; Travel nec.

Appendix Table A2. Coding rules for activities by K cohort children

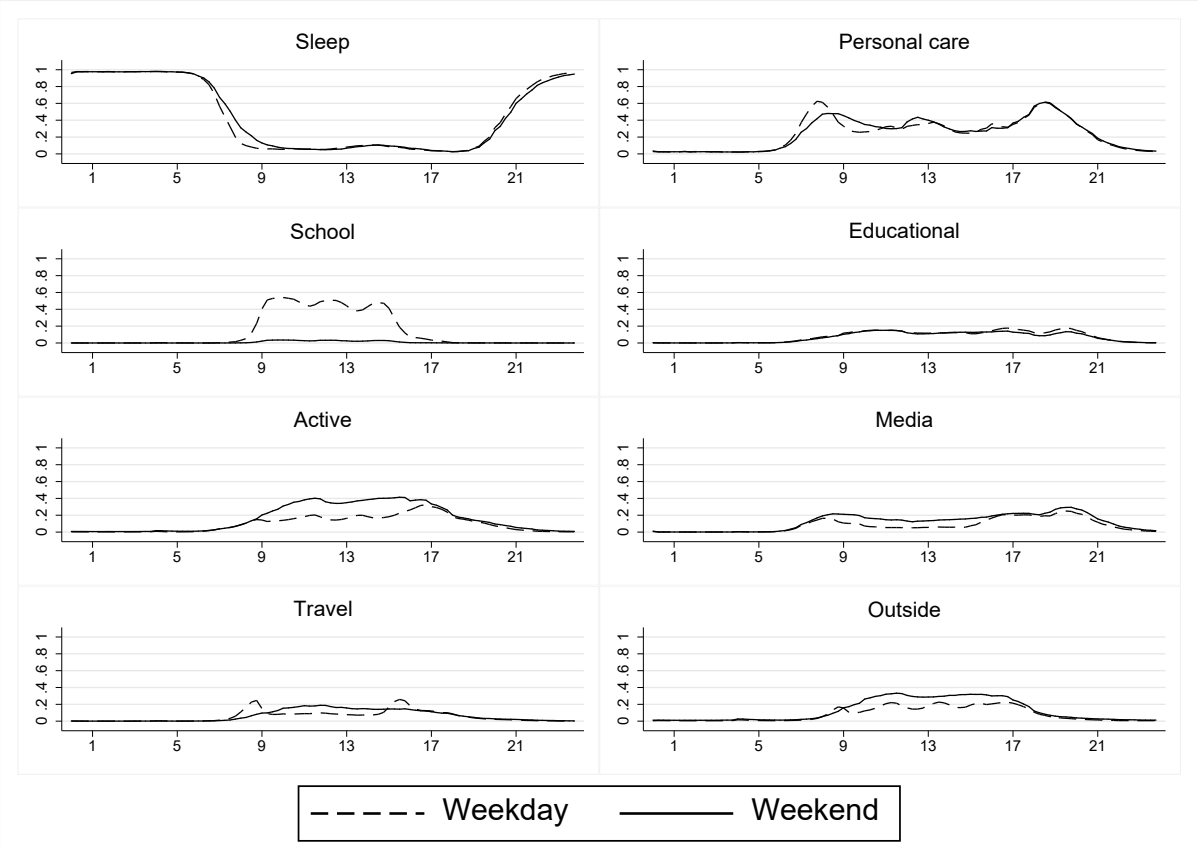
Grouping	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
Sleep	Sleeping, napping	Sleeping, napping	Same as wave 2	Sleeping/napping; Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")
Personal care	Awake in bed; Eating and drinking; Bathe, dress, hair care, health care; Do nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting, destroy things; Held, cuddled, comforted, soothed; Being reprimanded, corrected; Not sure what child was doing	Awake in bed; Eating and drinking; Bathe, dress, hair care, health care; Do nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting, destroy things; Held, cuddled, comforted, soothed; Being reprimanded, corrected; Quiet free play; Helping with chores/jobs; Not sure what child was doing	Same as wave 2	Eating/drinking; Bathing, dressing, toileting, teeth brushing, hair care; Dentist, Doctor, Chiropractor, Physio, Optometrist; Listening to music, CDs, playing music; Board or card games, puzzles, toys, art; Non-Active Club Activities i.e. Chess C; Doing nothing; Talking face to face; Making own bed, tidying own room; Making, preparing own food; Getting self ready, packing own school; Cleaning, tidying other rooms; Cooking, meal preparation, making lunch; Washing dishes, stacking and emptying d; Gardening, putting out the bin; Taking care of siblings, other children; Taking care of pets (excluding Walking	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec.; Doctor; Dentist; Physiotherapist / Chiropractor; Medical/Health care nec.; Listening to music, playing musical instruments or singing for leisure; Unstructured non-active play; Non-active club activities; Doing nothing; Non-active activities nec.; Talking face-to-face (in person not via electronic devices); Non-verbal interaction (e.g. cuddles); Negative face-to-face communication; Communication nec.; Filling out the diary; Retailing (including fast food); Pamphlet delivering; Umpiring/refereeing; Car washing; Gardening / lawn mowing; Babysitting; Animal care; Working in a family business or farm; Work nec.; Volunteering; Cleaning/tidying; Laundry/clothes care; Food/drink preparation; Food/drink clean up; Gardening / lawn mowing; Animal care (excluding active play); Home	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec; Doctor; Dentist/Orthodontist; Physiotherapist / Chiropractor; Medical/Health care; Personal care/Medical/Health Care nec.; Listening to music; Playing musical instruments or singing for leisure; Chess, card, paper and board games / crosswords; Games of chance / gambling; Hobbies, collections; Handwork crafts (excl. clothes making); Arts; Unstructured non-active play nec; Clubs; Religious groups; Doing nothing; Non-active activities nec; Talking face-to-face; Talking on a landline phone; Non-verbal interaction; Negative face-to-face communication; Communication nec; Illegal activities; Filling out the diary; Retailing; Hospitality (including fast food); Clerical/office; Labourers and related workers; Gardening / lawn mowing; Babysitting; Apprenticeships/trades persons; Working in a family business or farm; Work Other; Umpiring (work); Car washing (work); Animal care (work); Volunteering (work); Cleaning/tidying; Laundry/clothes care; Clothes making; Food/drink preparation; Food/drink clean up; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Animal care; Home maintenance; Design/Home Improvement;

Grouping	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
				pets); Other	maintenance; Taking care of siblings; Chores nec; Other	Heat/water/power upkeep; Car/boat/bike care; Selling/disposing of household assets; Rubbish/Recycling; Packing; Household management Other; Taking care of siblings (chores); Chores nec; Other; Uncodeable activity
School	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "School, after/; before school; care" to the question "where was the child?"	Same as wave 2	School Lessons, excluding Recess and Lunch	School Lessons, excluding Recess and Lunch	School Lessons, excluding Recess and Lunch
Education	Read a story, talk/sing, talked/sung to; colour, look at book, educational game; being taught to do chores, read, etc.; organised lessons / activities	Use computer/computer games (if this activity done for or as part of homework); Read a story, talk/sing, talked/sung to; Reading looking at book by self; Other organised lessons / activities	Same as wave 2	Private music, language, religion lessons, tutoring; Reading or being read to for leisure; Homework (not on computer) including music practice; Computer for homework - internet; Computer for homework - not internet	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework (electronic device); Attend courses (excluding school /university)
Active	Walk for travel or for fun; ride bicycle, trike etc. (travel or fun); other exercise - swim / dance/ run about; visiting	Walk for travel or for fun; Ride bicycle, trike etc. (travel for fun); Visiting people, special event, party; Organised sport/physical	Same as wave 2	Organised team sports and training i.e.; Organised individual sport i.e. swimming; Ball games, riding a bike, scooter, ska; Taking Pet for a walk; Scouts, girl guides, etc.;	Organised team sports and training; Organised individual sport and training; Unstructured active play; Walking pets / playing with pets; Active club activities; Shopping; Going out to a concert, play, museum, art gallery, community or school event , an amusement park	Archery / Shooting sports; Athletics / Gymnastics; Fitness / Gym / Exercise; Ball Sports; Martial arts / Dancing; Motor Sports / Roller Sports / Cycling; Water/Ice/Snow Sports; Organised team sports and training other; Archery / Shooting sports (individual); Athletics / Gymnastics (individual); Fitness / Gym / Exercise (individual); Martial arts / Dancing (individual); Motor Sports / Roller Sports

Grouping	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
	people, special event, party; other play, other activities	activity; Other organised lessons / activities		Shopping; Going out to museums, cultural events,; Cinema; Live Sporting Events	etc.; Religious activities / ritual ceremonies; Attending live sporting events; Active activities nec.	/ Cycling (individual); Ball Sports (individual); Water/Ice/Snow Sports (individual); Organised individual sport and training other; Archery / Shooting sports (unstructured); Athletics / Gymnastics (unstructured); Fitness / Gym / Exercise (unstructured); Ball Sports (unstructured); Martial arts / Dancing (unstructured); Motor Sports / Roller Sports / Cycling (unstructured); Water/Ice/Snow Sports (unstructured); Unstructured active play Other; Walking pets/playing with pets; Active club activities; Shopping; Shopping; Purchasing consumer goods; Purchasing durable goods; Window shopping; Purchasing repair services; Purchasing administrative services; Purchasing personal care services; Purchasing other services; Attendance at movies / cinema; Attendance at concert/theatre; Attendance at museum / exhibition / art gallery; Attendance at zoo / animal park / botanic garden; Attendance at other mass events; Going out nec; Religious practice; Weddings, funerals, rites of passage; Religious activities / ritual ceremonies nec; Attending live sporting events; Active activities nec.
Media	Watching TV, video, DVD, movie; Listening to tapes, CD's, radio, music; Use computer/computer games	Watching TV, video, DVD, movie; Listening to tapes, CD's, radio, music; Use computer/computer games (if this activity done NOT for or NOT as part of homework)	Same as wave 2	Electronic media, games, computer use; Computer games - internet; Computer games - not internet; Xbox, Playstation, Nintendo, WII etc.; Internet not covered elsewhere; TV/DVD; Talking on a landline phone; Talking on a mobile phone; Texting, email, social networking - facebook/twitter;	Playing games; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media (e.g. music, videos, applications); Internet shopping (excluding downloading/posting media); General Internet browsing (excluding homework); Creating/maintaining websites (excluding social networking profile); General application use (e.g. Microsoft Office; excluding homework); Electronic device use	Playing games (electronic device); Playing games (Electronic device) nfd.; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media; Internet shopping; General Internet browsing; Creating/maintaining websites; General application use; Electronic device use nec; Talking on a mobile phone; Video chatting; Texting/emailing; Online chatting / Instant messaging

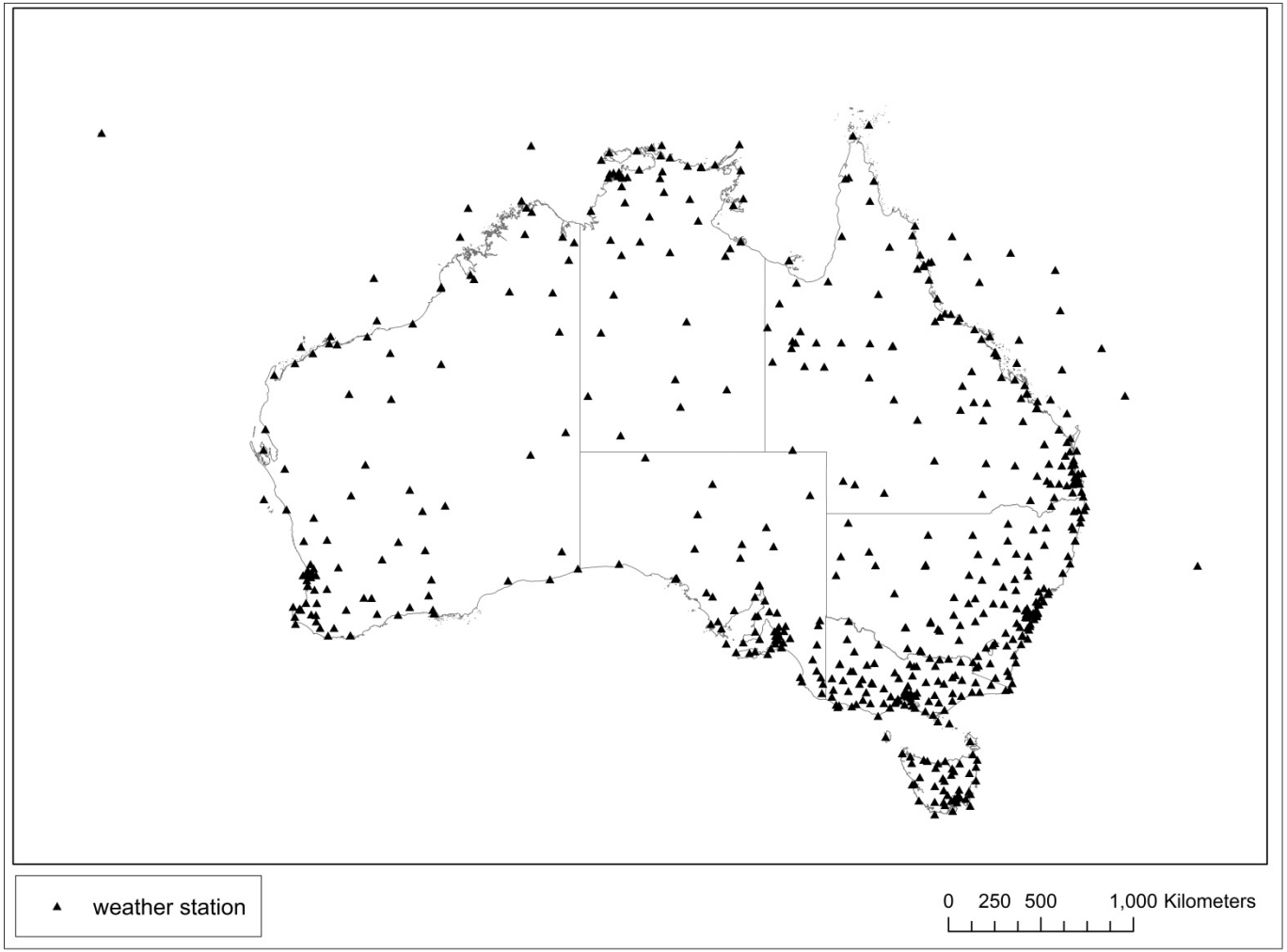
Grouping	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
				Skype or Webcam	nec.; Talking on a landline phone (not video chat); Talking on a mobile phone (not video chat); Video chatting (e.g. Skype); Texting/emailing; Online chatting / Instant messaging	
Travel	Travel in pusher or on bicycle seat; travel in car / other household vehicle; travel on public transport, ferry, plane; taken places with adult (e.g. shopping)	Travel in car; Travel on public transport; Taken places with adult (e.g. Shopping)	Same as wave 2	Travel by foot; by bike, scooter, skateboard etc.; by private car; Travel by public transport such as bus	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport such as bus, taxi or aeroplane; Travel nec.	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport; Travel nec.
Outdoor	Response "Other, outdoors" to the question "where was the child?"	Responses "Own home, outdoors" or "Other, outdoors" to the question "where was the child?"	Same as wave 2	Reponses "Yes" or "Both" to the question "Was the child outside?", plus Gardening, putting out the bin; Taking Pet for a walk; Travel by foot; Travel by bike, scooter, skateboard etc.	Reponses "Yes" or "Both" to the question "Was the child outside?", plus Pamphlet delivering; Car washing; gardening / lawn mowing; Travel by foot; Travel by bike, scooter, skateboard etc.; Travel nec.	Reponses "Yes" or "Both" to the question "Was the child outside?", plus Gardening / lawn mowing; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Travel by foot; Travel by bike, scooter, skateboard etc.; Travel nec.

Appendix Figure A4**.** Daily time-use pattern



Notes: This figure presents the allocation of children's time among various activities over a 24-hour period. Solid lines describe weekend patterns, while dashed lines describe weekday patterns. The vertical axis shows the proportion of children in a specific category, while the horizontal axis displays the time of the day.

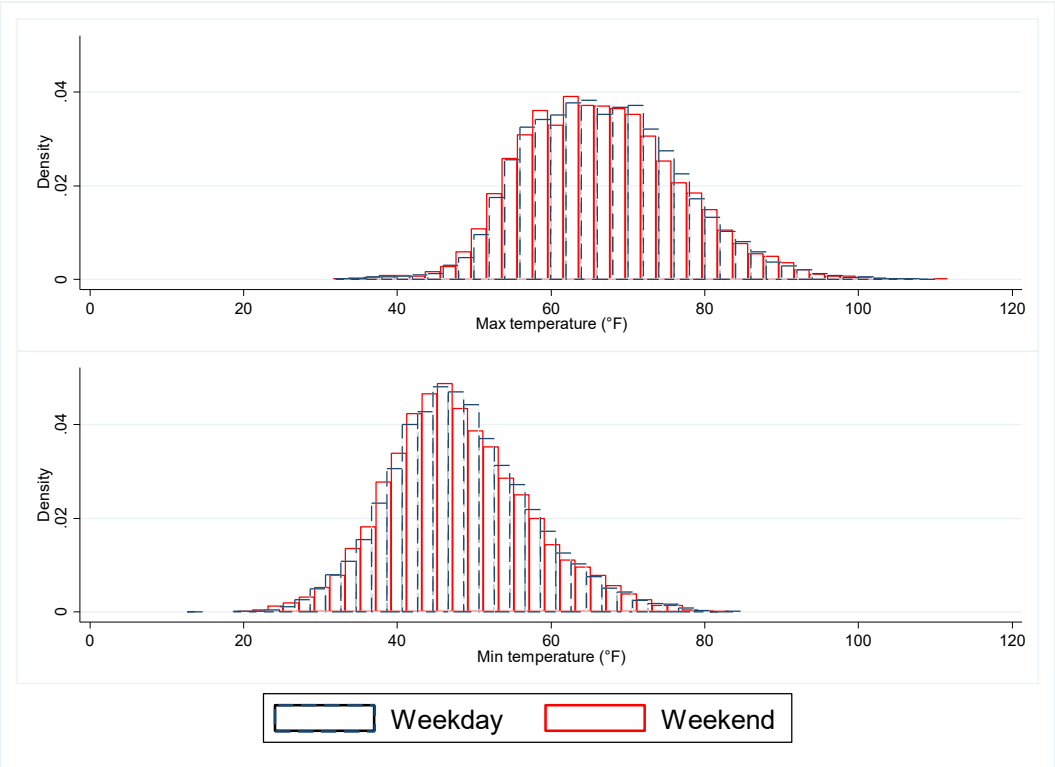
Appendix Figure A5. Distribution of weather stations



Sources: Authors' calculation from the BOM data.

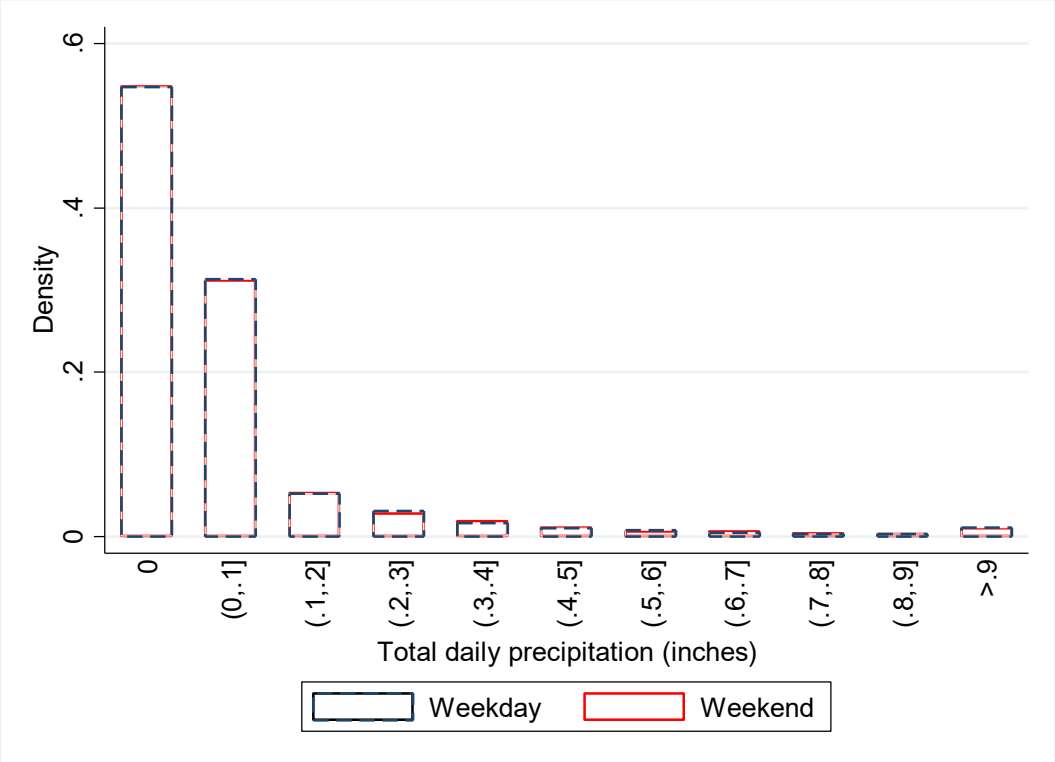
Appendix Figure A6. Histograms of daily temperature and precipitation

Panel A. Distribution of daily temperature



Notes: This figure presents the variations in daily maximum (minimum) temperature between 2004 and 2014 for those postcode-dates from which we have observations in our final sample.

Panel B. Distribution of daily precipitation



Notes: This figure presents the daily precipitation between 2004 and 2014 for those postcode-dates from which we have observations in our final sample.

Online Appendix B: Additional results, robustness checks and heterogeneity

Appendix Table B1. Does weather affect the time diary completion probability?

Variables	Marginal effects (1)
Child age (months)	-0.17**
Male	-2.55***
Aboriginal	-2.15
Child health	-2.08***
Low birth weight	-1.48
Mother age (years)	-0.03
Mother education: Certificate/Diploma [(a)]	0.64
Mother education: Bachelor or higher [(a)]	1.33
Maternal general health	-0.34
Mother employed part time [(b)]	0.31
Mother employed full time [(b)]	0.40
Mother ESB migrant [(c)]	-1.21
Mother NESB migrant [(c)]	0.28
Number of household members	-0.06
Number of younger siblings	-0.11
Number of older siblings	0.10
Living with both parents	2.75***
Weekly family income (AUS$ 1,000)	0.21
Homeowner	3.20***
Maximum temperature (°F)	-0.65*
Maximum temperature squared (°F)	0.00
Minimum temperature (°F)	-0.02
Precipitation (inches)	-1.37
Maximum relative humidity (%)	-0.07
Minimum relative humidity (%)	-0.01
Maximum wind speed (miles per hour)	-0.10
Minimum wind speed (miles per hour)	0.08
Maximum wind direction (degrees to the north)	0.00
Minimum wind direction (degrees to the north)	-0.00
Daylight (hours)	0.95
Observations	13,326
Number included in the sample	11,523
Pseudo R2	0.10
P t test	0.42

Notes: Results (marginal effects) are from a probit model. Marginal effects (multiplied by 100 for aesthetic purposes) are calculated at the means of continuous variables and from zero to one for dummy variables. The dependent variable is equal to one if the child is in our sample and zero otherwise. Sample: children of both cohorts surveyed in waves 4 to 6. [(a)], [(b)] and [(c)] denote no qualification, unemployed and native as the base group, respectively. Other explanatory variables include local socio-economic background variables, state/territory dummies, year dummies, month dummies, day-of-week dummies, and postcode dummies. P Chi 2 test: P value of a Chi square test for whether the estimates of all included weather variables are equal to zero. Robust standard errors clustered at the month-year-postcode level are not reported for brevity. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B2. Is weather good enough for outdoor activities?

	Estimates (ME)
Child age (months)	0.20
Male	2.19***
Aboriginal	3.36
Child health	-1.29**
Low birth weight	1.57
Mother age (years)	0.04
Mother education: Certificate/Diploma [(a)]	-0.21
Mother education: Bachelor or higher [(a)]	2.10*
Maternal general health	-1.07**
Mother employed part time [(b)]	1.68*
Mother employed full time [(b)]	1.11
Mother ESB migrant [(c)]	0.58
Mother NESB migrant [(c)]	-3.30**
Number of household members	-0.73
Number of younger siblings	0.33
Number of older siblings	1.84*
Living with both parents	2.52*
Weekly family income (AUS$ 1,000)	-0.34
Homeowner	0.39
Maximum temperature (81-83.5^{o}F is the base group)	
< 56.0 [(d)]	-27.08***
56.0- [(d)]	-21.11***
58.5- [(d)]	-18.52***
61.0- [(d)]	-15.26***
63.5 [(d)]	-14.65***
66.0- [(d)]	-13.48***
68.5- [(d)]	-11.63***
71.0- [(d)]	-9.29***
73.5- [(d)]	-6.73***
76.0- [(d)]	-2.24
78.5-81.0 [(d)]	-0.30
83.5- [(d)]	-8.46**
>86.0 [(d)]	-5.47
Minimum temperature (^{o}F)	-0.59***
Precipitation (inches)	-19.07***
Maximum relative humidity (%)	-0.23***
Minimum relative humidity (%)	-0.32***
Maximum wind speed (miles per hour)	-0.51***
Minimum wind speed (miles per hour)	0.17
Maximum wind direction (degrees to the north)	0.00
Minimum wind direction (degrees to the north)	-0.01*
Daylight (hours)	0.40
Observations	9,620

Notes: Results (marginal effects) are from a probit model. Marginal effects (multiplied by 100 for aesthetic purposes) are calculated at the means of continuous variables and from zero to one for dummy variables. The dependent variable is equal to one if the respondent reporting "Yes" to the question "Was the weather good enough for outdoor activities?" and zero otherwise. [(a)], [(b)], [(c)] and [(d)] denote no qualification, unemployed, native and 81-83.5 ^{0}F as the base group, respectively. Other explanatory variables include local socio-economic background variables, state/territory dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level are not reported for brevity. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B3. Determinants of children's time allocation - Remaining results

	Bed		Personal care		School		Education	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Child age (months)	-1.52***	-1.43***	-2.00***	-1.72***	2.37***	-0.04	1.54***	0.03
	[0.24]	[0.27]	[0.38]	[0.36]	[0.36]	[0.16]	[0.27]	[0.24]
Male	1.16	-5.42***	-15.42***	-20.36***	-0.63	-1.40*	-5.80***	-6.86***
	[1.52]	[1.58]	[2.20]	[2.03]	[2.06]	[0.80]	[1.72]	[1.50]
Aboriginal	4.44	-5.04	-5.02	0.85	-3.61	3.66	-20.72***	-10.59**
	[5.50]	[6.57]	[8.01]	[7.98]	[6.94]	[3.15]	[5.31]	[4.81]
Child general health	-4.10***	-1.02	-0.81	0.54	-3.82***	-0.47	-1.90*	-0.89
	[1.14]	[1.17]	[1.53]	[1.43]	[1.43]	[0.53]	[1.15]	[1.04]
Low birthweight	4.47	4.64	4.52	-5.25	-2.24	0.20	-7.50**	-2.28
	[3.27]	[3.52]	[4.83]	[4.17]	[4.48]	[1.70]	[3.33]	[3.06]
Mother's age (years)	-0.77***	-0.80***	-0.40	0.61***	-0.06	-0.05	0.99***	0.99***
	[0.18]	[0.19]	[0.26]	[0.24]	[0.24]	[0.09]	[0.19]	[0.17]
Mother education: Certificate/Diploma [(a)]	-1.79	-1.78	7.40***	2.72	-1.58	-0.81	7.36***	5.99***
	[2.00]	[2.16]	[2.82]	[2.70]	[2.55]	[1.04]	[2.12]	[1.86]
Mother education: Bachelor or higher [(a)]	-2.19	-1.12	24.73***	14.81***	-1.73	-1.01	29.14***	22.81***
	[2.16]	[2.26]	[3.05]	[2.90]	[2.92]	[1.11]	[2.47]	[2.16]
Maternal general health	-1.90**	-1.79*	4.46***	4.37***	0.58	1.26**	0.77	1.20
	[0.92]	[0.99]	[1.32]	[1.25]	[1.23]	[0.51]	[1.06]	[0.90]
Mother employed part time [(b)]	-2.20	-2.40	-7.91***	-7.19***	32.83***	0.05	-5.39**	-3.63*
	[1.94]	[1.97]	[2.60]	[2.42]	[2.49]	[0.92]	[2.10]	[1.87]
Mother employed full time [(b)]	-9.94***	-0.44	-5.20	-4.41	53.32***	0.90	-6.54**	-4.60**
	[2.30]	[2.56]	[3.43]	[3.17]	[3.33]	[1.25]	[2.65]	[2.33]
Mother ESB migrant [(c)]	-2.98	-2.52	4.13	1.90	1.52	1.46	4.70	2.75
	[2.60]	[2.81]	[3.95]	[3.57]	[3.75]	[1.41]	[2.98]	[2.67]
Mother NESB migrant [(c)]	-12.01***	-5.18*	-1.69	-4.57	4.44	3.83**	8.84***	13.91***
	[2.77]	[2.87]	[3.73]	[3.52]	[3.61]	[1.63]	[2.96]	[2.60]
Number of household members	1.82	1.32	5.97**	1.65	-1.73	-1.49**	-1.48	-1.41
	[1.60]	[1.61]	[2.35]	[2.16]	[2.01]	[0.70]	[1.60]	[1.43]

Number of younger siblings	-5.35***	-5.70***	-7.11**	1.66	-0.75	0.57	9.96***	8.69***
	[1.93]	[1.97]	[2.87]	[2.60]	[2.50]	[0.94]	[1.94]	[1.77]
Number of older siblings	-5.68***	-4.27**	-6.38**	-2.25	-3.25	0.98	-2.82	-1.94
	[1.91]	[1.87]	[2.67]	[2.47]	[2.31]	[0.77]	[1.86]	[1.66]
Biological parents are at home	0.82	1.65	1.79	2.40	-15.31***	-1.77	4.63*	6.00**
	[2.51]	[2.79]	[3.67]	[3.57]	[3.42]	[1.51]	[2.73]	[2.49]
Household weekly income	-0.66	-1.17**	-1.65**	-1.98***	2.34***	0.37	1.01	-1.17**
	[0.56]	[0.56]	[0.80]	[0.70]	[0.81]	[0.35]	[0.68]	[0.47]
Owned home	4.29**	3.16	-2.07	-3.68	-1.29	-0.65	7.44***	6.66***
	[2.05]	[2.12]	[2.90]	[2.71]	[2.70]	[1.04]	[2.20]	[1.96]
Tuesday [(d)]	-1.84	-2.65	6.82**	-1.13	16.25***	-2.48	5.43**	-2.30
	[2.29]	[4.23]	[3.31]	[6.47]	[3.15]	[3.45]	[2.52]	[3.70]
Wednesday [(d)]	-0.55	-10.66**	0.27	5.27	21.05***	-3.08	5.89**	-1.01
	[2.33]	[4.41]	[3.33]	[6.60]	[3.11]	[3.41]	[2.56]	[3.67]
Thursday [(d)]	-5.18**	-8.88*	0.09	-6.08	17.94***	4.40	6.22**	1.71
	[2.41]	[4.82]	[3.38]	[6.99]	[3.23]	[3.92]	[2.56]	[4.16]
Friday [(d)]	-19.87***	-23.58***	2.57	-3.48	2.68	11.67**	-4.39*	2.26
	[2.42]	[5.09]	[3.31]	[7.36]	[3.24]	[4.70]	[2.56]	[4.75]
Saturday [(d)]		-17.57***		-14.21***		-1.91		14.59***
		[3.52]		[4.67]		[2.76]		[3.10]
Sunday [(d)]		8.35**		-10.40**		-5.04*		10.33***
		[3.31]		[4.54]		[2.66]		[2.89]
K cohort	-12.37	2.86	25.67	15.50	16.42	9.02	-84.74***	-52.71***
	[11.72]	[12.82]	[18.10]	[17.12]	[17.17]	[7.69]	[13.05]	[11.90]

Notes: Results are from the equation (1). Other explanatory variables include weather conditions (results are reported in Table 2), local socio-economic background variables, year dummies, month dummies, state/territory dummies, and postcode dummies. [(a)], [(b)], [(c)], and [(d)] denote no qualification, unemployed, native, and Monday as the base group, respectively. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B3. Determinants of children's time allocation - Remaining results (continued)

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(9)	(10)	(13)	(14)	(15)	(16)	(17)	(18)
Child age (months)	-0.46*	0.67*	0.12	1.73***	-0.24	0.35	-0.80***	0.84**
	[0.27]	[0.35]	[0.25]	[0.31]	[0.17]	[0.22]	[0.27]	[0.38]
Male	12.08***	12.32***	15.27***	24.40***	0.45	-1.32	14.08***	19.85***
	[1.61]	[2.06]	[1.40]	[1.71]	[1.02]	[1.29]	[1.51]	[2.21]
Aboriginal	9.76	8.82	0.65	8.28	-5.13	-2.02	-2.11	13.15
	[7.22]	[7.90]	[5.01]	[6.41]	[3.74]	[4.51]	[5.61]	[8.49]
Child general health	-4.56***	-5.72***	6.18***	4.48***	-0.53	0.61	-1.79*	-6.17***
	[1.09]	[1.50]	[1.03]	[1.20]	[0.70]	[0.91]	[1.06]	[1.50]
Low birthweight	-2.63	-5.56	-4.65	1.22	-4.02*	-9.35***	-1.67	-6.86
	[3.28]	[4.28]	[3.05]	[3.74]	[2.09]	[2.60]	[3.33]	[4.35]
Mother's age (years)	0.36**	-0.27	0.22	0.33*	0.33***	-0.06	0.16	-0.15
	[0.18]	[0.24]	[0.17]	[0.20]	[0.12]	[0.15]	[0.17]	[0.25]
Mother education: Certificate/Diploma [(a)]	1.50	2.11	-2.56	1.50	2.55*	1.15	2.46	2.62
	[2.08]	[2.79]	[1.88]	[2.24]	[1.36]	[1.69]	[1.93]	[2.83]
Mother education: Bachelor or higher [(a)]	8.88***	8.89***	-17.24***	-15.00***	5.37***	3.29*	7.18***	5.59*
	[2.25]	[3.03]	[1.94]	[2.34]	[1.42]	[1.80]	[2.10]	[3.06]
Maternal general health	-1.99**	-2.04	3.14***	5.75***	0.29	-2.39***	-1.09	-1.88
	[1.01]	[1.25]	[0.86]	[1.03]	[0.63]	[0.77]	[0.90]	[1.33]
Mother employed part time [(b)]	-6.52***	11.51***	-13.41***	-8.62***	-0.05	4.91***	-1.35	12.67***
	[2.01]	[2.47]	[1.68]	[1.99]	[1.29]	[1.57]	[1.90]	[2.62]
Mother employed full time [(b)]	-14.02***	4.49	-11.38***	-4.65*	-2.64*	7.03***	-4.20*	9.36***
	[2.47]	[3.14]	[2.19]	[2.66]	[1.57]	[2.06]	[2.35]	[3.46]
Mother ESB migrant [(c)]	4.09	0.95	2.05	-1.69	1.52	-0.34	3.36	5.92
	[2.92]	[3.63]	[2.35]	[2.88]	[1.82]	[2.17]	[2.60]	[3.77]
Mother NESB migrant [(c)]	-8.03***	-25.76***	5.95**	0.83	-7.01***	3.29	-5.92**	-18.28***
	[2.74]	[3.50]	[2.62]	[3.14]	[1.79]	[2.37]	[2.66]	[3.74]
Number of household members	0.01	-4.33**	-2.04	-0.25	-1.09	-0.05	-0.49	1.27
	[1.72]	[1.99]	[1.48]	[1.86]	[1.02]	[1.38]	[1.48]	[2.14]
Number of younger siblings	1.40	10.68***	0.17	-6.69***	-0.18	-2.58	6.25***	7.31***

	[2.11]	[2.49]	[1.78]	[2.28]	[1.22]	[1.64]	[1.82]	[2.71]
Number of older siblings	2.00	7.00***	1.07	0.29	3.38***	-3.71**	3.35**	5.05**
	[1.98]	[2.33]	[1.70]	[2.10]	[1.21]	[1.59]	[1.71]	[2.54]
Biological parents are at home	8.65***	11.06***	-2.36	-7.69**	1.05	1.80	3.14	1.70
	[2.75]	[3.43]	[2.52]	[3.24]	[1.69]	[2.17]	[2.59]	[3.87]
Household weekly income	-0.11	0.48	-0.71	0.03	0.80**	0.26	-0.37	-0.72
	[0.55]	[0.68]	[0.52]	[0.61]	[0.35]	[0.41]	[0.59]	[0.71]
Owned home	-0.88	5.54**	-8.80***	-6.30***	2.62*	0.50	2.59	7.16**
	[2.02]	[2.75]	[1.93]	[2.23]	[1.43]	[1.71]	[2.00]	[2.92]
Tuesday [(d)]	-9.34***	3.55	-5.01**	19.87***	1.01	-6.15	-7.01***	-11.05*
	[2.50]	[6.32]	[2.10]	[6.85]	[1.55]	[3.78]	[2.36]	[6.55]
Wednesday [(d)]	-13.03***	-1.35	-6.35***	15.59**	1.83	-3.10	-10.15***	-14.04**
	[2.38]	[6.27]	[2.07]	[6.78]	[1.58]	[3.91]	[2.24]	[6.72]
Thursday [(d)]	-9.61***	1.59	-5.85***	4.82	5.65***	5.16	-4.75**	-2.06
	[2.46]	[6.51]	[2.09]	[6.77]	[1.61]	[4.22]	[2.36]	[7.69]
Friday [(d)]	2.18	-0.59	12.11***	13.11*	10.92***	11.78**	1.82	-7.95
	[2.59]	[7.33]	[2.18]	[7.17]	[1.68]	[4.68]	[2.48]	[8.01]
Saturday [(d)]		7.20		-1.51		0.79		11.37**
		[5.01]		[4.69]		[3.13]		[5.29]
Sunday [(d)]		3.96		-10.84**		-11.37***		2.37
		[4.68]		[4.59]		[2.91]		[4.96]
K cohort	-13.80	-17.59	19.07	-17.21	-2.18	-18.57*	28.01**	-26.95
	[13.02]	[17.02]	[11.98]	[15.14]	[8.12]	[10.70]	[12.93]	[18.33]

Notes: Results are from the equation (1). Other explanatory variables include weather conditions (results are reported in Table 2), local socio-economic background variables, year dummies, month dummies, state/territory dummies, and postcode dummies. [(a)], [(b)], [(c)], and [(d)] denote no qualification, unemployed, native, and Monday as the base group, respectively. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B4. Inter-day substitution – Impacts of weather conditions over the next day

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Current max temperature (°F)	3.48***	3.97**	-2.52*	-3.28**	0.42	2.00**	3.60***	10.52***
	[1.30]	[1.65]	[1.42]	[1.42]	[0.85]	[1.01]	[1.15]	[1.67]
Current max temperature sq.	-0.02**	-0.02**	0.02	0.03**	-0.00	-0.02**	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Current precipitation (inches)	-12.66***	-11.42*	0.04	15.42***	-6.53***	-1.20	-21.36***	-21.57***
	[3.58]	[6.27]	[3.33]	[5.12]	[2.10]	[4.89]	[3.18]	[7.28]
Leaded max temperature (°F)	1.09	1.59	1.32	-1.66	0.12	-0.56	-0.27	0.19
	[1.27]	[1.73]	[1.21]	[1.53]	[0.82]	[1.05]	[1.26]	[1.84]
Leaded max temperature sq.	-0.01	-0.01	-0.01	0.01	-0.00	0.00	0.00	-0.00
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Leaded precipitation (inches)	-2.96	-4.35	7.09*	7.13*	-6.37**	-1.57	-6.89	-12.57**
	[4.06]	[5.50]	[4.00]	[4.23]	[2.66]	[3.66]	[4.44]	[6.31]
Observations	22,944	22,402	22,944	22,402	22,944	22,402	22,944	22,402
R-squared	0.195	0.146	0.089	0.247	0.074	0.068	0.100	0.133

Notes: This table reports the impact of various (both contemporaneous and leaded) weather conditions on children's time allocation. Results are from equation (1). Leaded weather conditions are defined over the next day. The list of covariates includes other (both contemporaneous and forwarded) weather variables such as minimum daily temperature, humidity, wind speed, wind direction and (contemporaneous) daylight. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B5. Proportion (%) of children with zero time use for grouped activities

	Weekday	Weekend	All
Activity	(1)	(2)	(3)
Bed	0.06	0.11	0.08
Personal care	0.02	0.03	0.02
School	41.79	94.46	67.81
Educational	21.64	27.16	24.37
Active	15.95	7.71	11.88
Media	14.77	10.65	12.73
Travel	12.25	21.44	16.79
Outdoor	26.06	19.22	22.68

Notes: This table reports the proportion (%) of children with zero time allocated to various grouped activities.

Appendix Table B6. Robustness checks - Results for a pooled sample of weekdays and weekends

	Sleep	Personal care	School	Education	Active	Media	Travel	Outdoor
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	1.44*	-1.78*	0.58	1.27	4.09***	-2.70***	0.99*	6.69***
	[0.77]	[1.04]	[0.79]	[0.79]	[0.87]	[0.88]	[0.53]	[0.84]
Max temperature sq.	-0.01**	0.01	-0.00	-0.01*	-0.02***	0.02***	-0.01**	-0.04***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]
Min temperature (°F)	-0.16	-0.00	-0.18	0.00	-0.25	0.15	-0.20*	-0.33*
	[0.15]	[0.20]	[0.17]	[0.15]	[0.19]	[0.15]	[0.11]	[0.18]
Precipitation (inches)	4.70*	4.22	-4.54	0.72	-12.68***	8.81***	-4.78*	-23.24***
	[2.43]	[3.89]	[3.44]	[3.69]	[3.51]	[3.00]	[2.49]	[3.71]
Max humidity (%)	-0.10	0.14	0.11	0.11	0.03	-0.00	0.00	-0.18*
	[0.08]	[0.11]	[0.10]	[0.09]	[0.10]	[0.09]	[0.06]	[0.10]
Min humidity (%)	-0.07	0.05	0.13*	-0.00	-0.05	-0.03	0.00	-0.07
	[0.07]	[0.09]	[0.08]	[0.07]	[0.08]	[0.07]	[0.05]	[0.08]
Max wind speed (mph)	0.12	0.14	0.05	-0.07	-0.09	-0.15	-0.02	-0.37***
	[0.10]	[0.13]	[0.12]	[0.09]	[0.11]	[0.09]	[0.07]	[0.11]
Min wind speed (mph)	-0.16	0.27	0.34	-0.12	0.08	0.17	0.13	-0.37
	[0.21]	[0.28]	[0.24]	[0.21]	[0.25]	[0.21]	[0.16]	[0.24]
Max wind direction	-0.01	0.01	-0.02*	0.00	-0.01	0.02	-0.01	-0.02
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Min wind direction	0.00	-0.01	-0.02	0.02	-0.01	0.02*	-0.02**	-0.02
	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Daylight (hours)	-4.61***	-2.30	5.35***	2.81*	0.75	-1.41	0.06	4.71**
	[1.69]	[2.04]	[1.79]	[1.58]	[1.73]	[1.51]	[1.03]	[1.88]
Weekends	19.99***	22.17***	-196.32***	-21.33***	70.21***	86.16***	10.95***	35.95***
	[1.89]	[2.75]	[2.30]	[1.70]	[2.57]	[2.68]	[1.64]	[2.76]
Observations	45,347	45,347	45,347	45,347	45,347	45,347	45,347	45,347
R-squared	0.277	0.099	0.428	0.130	0.205	0.191	0.058	0.137
Sample mean	651.1	336.2	105.4	102.7	180.6	140.5	84.47	137.3

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B7. Robustness checks - Excluding diaries completed on unscheduled dates

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	4.24***	4.33***	-1.07	-3.76***	-0.17	1.64*	2.87***	10.68***
	[1.10]	[1.43]	[1.26]	[1.25]	[0.75]	[0.84]	[1.05]	[1.44]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	0.00	-0.01**	-0.01*	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.33	-0.24	0.24	0.06	-0.01	-0.33*	-0.25	-0.89***
	[0.23]	[0.31]	[0.20]	[0.25]	[0.15]	[0.19]	[0.22]	[0.33]
Precipitation (inches)	-10.39***	-16.19**	2.61	19.65***	-5.38**	1.16	-26.20***	-25.62***
	[3.61]	[7.16]	[3.35]	[5.81]	[2.26]	[5.31]	[3.66]	[8.39]
Max humidity (%)	-0.17	0.11	0.11	-0.23*	-0.02	0.04	-0.24*	-0.29*
	[0.13]	[0.16]	[0.11]	[0.14]	[0.08]	[0.10]	[0.12]	[0.17]
Min humidity (%)	0.01	-0.22	-0.18*	0.28**	-0.03	-0.11	0.12	-0.20
	[0.11]	[0.14]	[0.09]	[0.12]	[0.07]	[0.09]	[0.10]	[0.15]
Max wind speed (mph)	-0.18	-0.34*	-0.09	-0.11	-0.08	-0.21*	-0.25**	-0.71***
	[0.14]	[0.20]	[0.14]	[0.16]	[0.08]	[0.12]	[0.13]	[0.21]
Min wind speed (mph)	0.57*	-0.11	0.43	0.20	-0.03	0.32	0.37	-0.91**
	[0.31]	[0.42]	[0.29]	[0.34]	[0.19]	[0.25]	[0.31]	[0.43]
Max wind direction	-0.02	-0.01	0.02	0.01	-0.02	0.00	-0.03*	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.00	-0.00	0.01	0.03	-0.00	-0.02	-0.01	0.00
	[0.02]	[0.02]	[0.02]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-1.30	4.40	-1.35	-2.86	-2.21	0.74	0.63	7.82**
	[2.37]	[3.06]	[2.15]	[2.30]	[1.47]	[1.81]	[2.37]	[3.44]
Observations	18,564	18,894	18,564	18,894	18,564	18,894	18,564	18,894
R-squared	0.166	0.146	0.091	0.247	0.067	0.065	0.110	0.128
Sample mean	123.4	224.5	114.6	174.1	76.30	86.38	104.8	178.3

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B8. Robustness checks - Including only Saturdays and Sundays in weekends

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.44***	5.82***	-1.91*	-4.26***	0.44	2.00**	4.02***	11.11***
	[1.00]	[1.51]	[1.13]	[1.19]	[0.63]	[0.89]	[0.91]	[1.46]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.02***	-0.02***	-0.07***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.33	-0.50	0.11	-0.03	-0.20	-0.28	-0.32	-0.65**
	[0.21]	[0.33]	[0.20]	[0.24]	[0.13]	[0.20]	[0.20]	[0.33]
Precipitation (inches)	-9.86***	-14.11*	7.07**	18.88***	-7.55***	1.34	-24.16***	-18.47**
	[3.43]	[7.74]	[3.47]	[6.08]	[1.94]	[6.17]	[3.06]	[8.89]
Max humidity (%)	-0.13	0.09	0.03	-0.18	0.03	-0.05	-0.23**	-0.24
	[0.12]	[0.17]	[0.12]	[0.13]	[0.07]	[0.11]	[0.11]	[0.18]
Min humidity (%)	0.03	-0.05	-0.18*	0.27**	0.02	-0.01	0.10	-0.22
	[0.09]	[0.15]	[0.09]	[0.11]	[0.06]	[0.09]	[0.09]	[0.15]
Max wind speed (mph)	-0.15	-0.11	-0.15	-0.14	0.07	-0.20	-0.22*	-0.68***
	[0.12]	[0.22]	[0.13]	[0.15]	[0.08]	[0.13]	[0.12]	[0.21]
Min wind speed (mph)	0.50*	-0.17	0.44	0.29	-0.06	0.50*	-0.18	-0.61
	[0.28]	[0.44]	[0.27]	[0.33]	[0.18]	[0.27]	[0.27]	[0.44]
Max wind direction	0.00	-0.02	0.02	0.00	-0.01	0.00	-0.01	-0.03
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.01	0.02	0.03**	0.00	-0.01	-0.03**	0.01	0.00
	[0.02]	[0.02]	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]	[0.02]
Daylight (hours)	-1.46	2.35	-2.99	-1.20	-1.76	2.75	1.95	6.78**
	[2.05]	[2.85]	[1.98]	[2.07]	[1.18]	[1.89]	[2.00]	[3.19]
Observations	27,168	18,179	27,168	18,179	27,168	18,179	27,168	18,179
R-squared	0.159	0.118	0.155	0.203	0.067	0.065	0.099	0.142
Sample mean	142.2	238.1	132.8	152.1	79.82	91.42	112.1	174.9

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B9. Robustness checks – Controlling for individual fixed effects

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.52***	2.91*	-2.28*	-3.82***	0.69	1.73*	3.46***	9.61***
	[1.22]	[1.61]	[1.23]	[1.29]	[0.80]	[1.01]	[1.20]	[1.59]
Max temperature squared	-0.02**	-0.02	0.01	0.03***	-0.00	-0.01**	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.72***	-0.54	0.25	0.00	-0.24	-0.39*	-0.77***	-0.77**
	[0.26]	[0.33]	[0.22]	[0.26]	[0.16]	[0.21]	[0.24]	[0.34]
Precipitation (inches)	-16.97***	-13.78*	5.74	20.71***	-5.88**	-6.26	-16.80***	-29.40***
	[4.08]	[7.21]	[3.85]	[5.55]	[2.67]	[6.19]	[3.91]	[8.44]
Max humidity (%)	0.07	-0.11	0.16	-0.09	0.02	0.12	-0.26*	-0.35*
	[0.14]	[0.18]	[0.12]	[0.15]	[0.09]	[0.12]	[0.14]	[0.18]
Min humidity (%)	0.08	0.01	-0.19*	0.17	0.03	-0.01	0.15	-0.10
	[0.12]	[0.16]	[0.10]	[0.12]	[0.08]	[0.10]	[0.11]	[0.16]
Max wind speed (mph)	0.10	-0.17	-0.09	-0.20	-0.05	-0.11	-0.14	-0.34
	[0.15]	[0.21]	[0.13]	[0.16]	[0.10]	[0.13]	[0.14]	[0.22]
Min wind speed (mph)	0.56	-0.58	0.18	0.28	0.07	0.57**	0.02	-1.20***
	[0.34]	[0.45]	[0.30]	[0.36]	[0.23]	[0.28]	[0.32]	[0.46]
Max wind direction	-0.02	-0.03	0.00	-0.00	0.00	-0.00	-0.02	-0.05*
	[0.02]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]	[0.02]	[0.03]
Min wind direction	-0.01	0.01	0.01	-0.00	-0.01	-0.02	-0.01	0.02
	[0.02]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]	[0.02]	[0.02]
Daylight (hours)	-0.87	4.37	-0.62	-2.03	-2.39	3.51*	4.37*	4.85
	[2.59]	[3.41]	[2.08]	[2.42]	[1.53]	[2.10]	[2.37]	[3.41]
Observations	21,439	20,816	21,439	20,816	21,439	20,816	21,439	20,816
R-squared	0.185	0.146	0.030	0.194	0.062	0.056	0.083	0.092
Sample mean	6,630	6,398	6,630	6,398	6,630	6,398	6,630	6,398

Notes: This table reports regression coefficients from fixed effects models of the impact of various weather conditions on children's time allocation. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, and day-of-week dummies. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the child individual level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B10. Robustness checks - Excluding individual level explanatory variables

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.80***	4.81***	-1.93*	-4.51***	0.28	1.82**	3.30***	10.47***
	[1.06]	[1.32]	[1.17]	[1.19]	[0.68]	[0.80]	[0.93]	[1.33]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.01***	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.37*	-0.38	0.24	0.04	-0.15	-0.33*	-0.28	-0.75**
	[0.22]	[0.29]	[0.19]	[0.24]	[0.14]	[0.17]	[0.20]	[0.30]
Precipitation (inches)	-11.92***	-12.77**	1.02	16.96***	-7.10***	-1.00	-22.43***	-24.18***
	[3.58]	[6.02]	[3.26]	[5.21]	[2.10]	[4.85]	[3.24]	[7.06]
Max humidity (%)	-0.01	0.02	0.07	-0.08	-0.03	0.00	-0.18*	-0.23
	[0.12]	[0.15]	[0.11]	[0.13]	[0.08]	[0.10]	[0.11]	[0.16]
Min humidity (%)	0.04	-0.07	-0.15	0.19*	0.04	-0.04	0.12	-0.14
	[0.10]	[0.13]	[0.09]	[0.11]	[0.07]	[0.08]	[0.09]	[0.14]
Max wind speed (mph)	-0.02	-0.28	-0.19	-0.20	0.08	-0.17	-0.21*	-0.66***
	[0.13]	[0.19]	[0.12]	[0.15]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.43	-0.22	0.47*	0.27	-0.09	0.36	0.17	-0.87**
	[0.30]	[0.39]	[0.27]	[0.32]	[0.19]	[0.23]	[0.28]	[0.39]
Max wind direction	-0.01	-0.01	0.02	-0.00	-0.01	-0.00	-0.02	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.00	0.01	0.01	0.02	-0.01	-0.02*	-0.01	0.01
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-2.75	1.30	1.66	-2.60	-3.16**	3.12*	-0.33	6.47**
	[2.14]	[2.66]	[1.94]	[2.12]	[1.25]	[1.69]	[2.08]	[2.92]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.172	0.134	0.054	0.181	0.063	0.064	0.092	0.121
Sample mean	136.8	225.5	114.0	167.7	79.80	89.26	103.8	171.5

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include state/territory dummies, postcode dummies, year dummies, month dummies, and day-of-week dummies. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B11. Robustness checks – Estimates from two-part models

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.98***	4.53***	-1.71	-4.20***	0.27	1.95**	3.70***	10.39***
	[1.06]	[1.32]	[1.12]	[1.11]	[0.69]	[0.83]	[0.98]	[1.33]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.02***	-0.02***	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.41*	-0.35	0.28	0.03	-0.17	-0.32*	-0.30	-0.73**
	[0.21]	[0.29]	[0.19]	[0.23]	[0.14]	[0.17]	[0.20]	[0.30]
Precipitation (inches)	-13.69***	-12.03**	1.62	16.08***	-7.72***	-1.08	-24.93***	-25.32***
	[3.80]	[6.08]	[3.20]	[5.05]	[2.18]	[5.13]	[3.79]	[7.35]
Max humidity (%)	-0.03	-0.01	0.10	-0.12	-0.02	0.01	-0.19*	-0.26*
	[0.12]	[0.15]	[0.11]	[0.12]	[0.08]	[0.09]	[0.11]	[0.16]
Min humidity (%)	0.07	-0.06	-0.18**	0.20*	0.05	-0.03	0.14	-0.13
	[0.10]	[0.13]	[0.09]	[0.10]	[0.06]	[0.08]	[0.10]	[0.13]
Max wind speed (mph)	-0.02	-0.27	-0.16	-0.11	0.08	-0.17	-0.20	-0.60***
	[0.13]	[0.18]	[0.12]	[0.14]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.47	-0.27	0.44*	0.29	-0.05	0.37	0.19	-0.98**
	[0.29]	[0.38]	[0.27]	[0.31]	[0.19]	[0.23]	[0.29]	[0.39]
Max wind direction	-0.01	-0.02	0.02	-0.00	-0.01	-0.00	-0.01	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.01	0.01	0.01	0.01	-0.01	-0.02	-0.01	0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-0.82	2.02	0.24	-2.04	-2.42*	3.34**	0.16	7.70***
	[2.05]	[2.63]	[1.86]	[1.98]	[1.26]	[1.66]	[2.08]	[2.83]
Observations	22,886	22,126	22,865	22,053	22,840	22,377	22,859	22,358

Notes: This table reports unconditional marginal effects (from two-part models) of various weather conditions on children's time allocation. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B12. Robustness checks - Including separate indicators for daily maximum temperature and rainy day dummy

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
Maximum temperature[(a)]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
< 56.0	-22.45***	-22.49**	8.93	4.32	-6.02	0.21	-24.07***	-48.37***
	[6.68]	[8.88]	[5.98]	[7.28]	[4.51]	[5.47]	[6.30]	[9.29]
56.0-	-20.59***	-13.49	9.62*	1.84	-5.85	2.08	-25.34***	-40.28***
	[6.05]	[8.25]	[5.54]	[6.60]	[4.16]	[5.01]	[5.78]	[8.52]
58.5-	-15.83***	-13.31*	10.54**	-3.02	-4.91	3.49	-18.27***	-27.82***
	[5.67]	[7.50]	[5.19]	[6.25]	[3.83]	[4.75]	[5.54]	[8.18]
61.0-	-13.45**	-14.87**	9.81**	-1.38	-6.04*	4.21	-20.26***	-25.05***
	[5.42]	[6.96]	[4.83]	[5.76]	[3.55]	[4.37]	[5.18]	[7.60]
63.5-	-4.22	-6.61	6.72	2.93	-6.07*	0.63	-11.55**	-16.79**
	[5.18]	[6.59]	[4.50]	[5.40]	[3.34]	[4.20]	[4.92]	[7.14]
66.0-	-9.56*	-8.44	7.16*	-0.73	-4.03	-0.52	-10.31**	-12.44*
	[4.97]	[6.17]	[4.34]	[5.15]	[3.22]	[3.79]	[4.63]	[6.91]
68.5-	-0.43	-0.31	6.05	-1.06	-1.34	-0.30	-9.87**	-6.00
	[4.63]	[6.06]	[4.18]	[4.94]	[3.14]	[3.83]	[4.48]	[6.60]
71.0-	-1.71	-0.03	5.15	0.97	-2.10	1.48	-5.81	-6.60
	[4.72]	[5.97]	[4.00]	[4.92]	[2.95]	[3.64]	[4.52]	[6.42]
73.5-	-2.07	0.88	-2.67	-2.81	0.20	4.94	-3.33	-0.73
	[4.70]	[6.00]	[3.87]	[4.91]	[3.16]	[3.94]	[4.69]	[6.55]
76.0-	9.08	-1.60	4.01	14.01**	4.94	0.93	0.98	1.48
	[5.65]	[6.48]	[4.47]	[5.54]	[3.61]	[4.43]	[5.00]	[7.67]
78.5-81.0	4.41	-1.09	-0.13	10.30*	-3.29	-3.94	2.06	-9.59
	[6.12]	[7.75]	[5.20]	[6.26]	[3.63]	[4.65]	[5.66]	[8.45]
83.5-	-0.02	1.80	-3.93	22.67***	1.22	-9.94*	-0.45	-6.02
	[6.56]	[9.22]	[5.46]	[7.32]	[4.45]	[5.89]	[6.66]	[9.76]
>86.0	-1.24	-5.88	3.84	16.29**	-2.12	-6.07	-4.32	-12.04
	[6.32]	[8.19]	[6.08]	[7.46]	[4.21]	[5.23]	[6.19]	[8.92]
Rainy day	-7.57***	-7.81**	-0.67	7.04**	-4.92***	-1.69	-10.04***	-13.31***
	[2.58]	[3.57]	[2.36]	[2.81]	[1.64]	[2.10]	[2.52]	[3.62]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.195	0.145	0.089	0.247	0.074	0.068	0.099	0.132

Notes: This table reports estimates regression coefficients of categorised daily maximum temperature on children's time allocation based on equation (1). [(a)] denotes 81-83.5 ^{0}F as the base group. Weather variables such as daily minimum temperature, humidity, wind speed, wind direction and daylight are included. Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Robust standard errors clustered at the month-year-postcode level in square brackets.

Appendix Table B13. Robustness checks – Excluding daily minimum temperature

	Active		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.81***	4.53***	-1.50	-4.20***	0.21	1.57**	3.14***	9.95***
	[1.05]	[1.30]	[1.13]	[1.12]	[0.67]	[0.78]	[0.91]	[1.30]
Max temperature sq.	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.01***	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Precipitation (inches)	-13.86***	-13.74**	1.87	17.06***	-7.91***	-1.79	-23.29***	-25.51***
	[3.49]	[6.08]	[3.23]	[5.01]	[2.10]	[4.82]	[3.23]	[7.16]
Max humidity (%)	0.04	0.05	0.06	-0.15	-0.00	0.07	-0.15	-0.14
	[0.12]	[0.14]	[0.11]	[0.12]	[0.07]	[0.09]	[0.11]	[0.15]
Min humidity (%)	-0.05	-0.17*	-0.09	0.21***	0.00	-0.14**	0.04	-0.36***
	[0.07]	[0.10]	[0.07]	[0.08]	[0.05]	[0.06]	[0.07]	[0.10]
Max wind speed (mph)	-0.08	-0.30*	-0.14	-0.10	0.05	-0.21*	-0.26**	-0.71***
	[0.13]	[0.18]	[0.12]	[0.14]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.42	-0.28	0.51*	0.21	-0.11	0.33	0.16	-1.00***
	[0.29]	[0.39]	[0.27]	[0.31]	[0.19]	[0.23]	[0.28]	[0.38]
Max wind direction	-0.01	-0.01	0.02	-0.00	-0.01	-0.00	-0.02	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.01	0.00	0.01	0.01	-0.01	-0.02*	-0.01	0.01
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-1.29	1.83	0.73	-2.39	-2.65**	2.75	0.25	6.48**
	[2.08]	[2.63]	[1.91]	[2.00]	[1.24]	[1.68]	[2.06]	[2.88]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.195	0.145	0.088	0.247	0.074	0.068	0.100	0.132

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B14. Robustness checks – Using daily mean temperature

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean temperature (°F)	2.73**	2.97**	-0.76	-3.16**	-0.05	0.90	2.38**	7.34***
	[1.16]	[1.47]	[1.22]	[1.23]	[0.71]	[0.89]	[1.05]	[1.48]
Mean temperature sq.	-0.02*	-0.02*	0.01	0.03***	0.00	-0.01*	-0.01	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Precipitation (inches)	-14.68***	-14.32**	2.18	17.38***	-7.97***	-1.77	-24.16***	-26.77***
	[3.49]	[6.13]	[3.24]	[5.02]	[2.10]	[4.85]	[3.29]	[7.29]
Max humidity (%)	0.10	0.11	0.04	-0.13	0.00	0.02	-0.06	-0.05
	[0.12]	[0.15]	[0.11]	[0.12]	[0.07]	[0.09]	[0.11]	[0.15]
Min humidity (%)	-0.18***	-0.31***	-0.04	0.18**	-0.02	-0.05	-0.13**	-0.62***
	[0.07]	[0.09]	[0.06]	[0.07]	[0.05]	[0.06]	[0.06]	[0.09]
Max wind speed (mph)	-0.15	-0.37**	-0.13	-0.07	0.05	-0.19*	-0.33***	-0.84***
	[0.13]	[0.18]	[0.12]	[0.14]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.44	-0.23	0.48*	0.16	-0.10	0.37	0.17	-0.86**
	[0.29]	[0.39]	[0.27]	[0.31]	[0.19]	[0.23]	[0.28]	[0.38]
Max wind direction	-0.01	-0.01	0.02	-0.00	-0.01	-0.00	-0.01	-0.01
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Min wind direction	-0.02	-0.01	0.01	0.01	-0.01	-0.02*	-0.02	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]
Daylight (hours)	-0.63	3.00	-0.21	-2.92	-2.30*	3.20*	1.03	9.35***
	[2.08]	[2.63]	[1.91]	[2.01]	[1.24]	[1.69]	[2.06]	[2.92]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.195	0.145	0.088	0.247	0.074	0.067	0.099	0.131

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B15. Robustness checks - Using different time intervals for weather conditions

	Active activity		Media		Travel		Outdoor	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Max temperature (°F)	3.98***	4.83***	-1.61	-4.31***	0.33	1.85**	3.32***	10.66***
	[1.06]	[1.31]	[1.14]	[1.13]	[0.68]	[0.80]	[0.92]	[1.31]
Max temperature squared	-0.02***	-0.03***	0.01	0.03***	-0.00	-0.02***	-0.02**	-0.06***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]
Min temperature (°F)	-0.39*	-0.41	0.25	0.04	-0.15	-0.30*	-0.29	-0.85***
	[0.21]	[0.30]	[0.19]	[0.23]	[0.14]	[0.18]	[0.20]	[0.30]
Precipitation (inches)	-13.70***	-14.34**	2.99	20.00***	-7.35***	-0.14	-25.09***	-28.45***
	[3.98]	[7.10]	[3.76]	[5.43]	[2.40]	[5.79]	[3.62]	[8.64]
Max humidity (%)	-0.02	-0.04	0.08	-0.14	-0.04	0.03	-0.20*	-0.26
	[0.12]	[0.15]	[0.11]	[0.12]	[0.08]	[0.10]	[0.11]	[0.16]
Min humidity (%)	0.05	-0.04	-0.16*	0.19*	0.05	-0.06	0.12	-0.10
	[0.10]	[0.13]	[0.09]	[0.11]	[0.07]	[0.08]	[0.09]	[0.13]
Max wind speed (mph)	-0.03	-0.30	-0.15	-0.11	0.09	-0.20*	-0.21*	-0.66***
	[0.13]	[0.19]	[0.12]	[0.15]	[0.09]	[0.11]	[0.12]	[0.19]
Min wind speed (mph)	0.53*	-0.07	0.34	0.24	-0.13	0.35	0.15	-0.76**
	[0.28]	[0.38]	[0.26]	[0.30]	[0.19]	[0.23]	[0.26]	[0.39]
Max wind direction	-0.01	-0.01	0.02	-0.00	-0.01	0.00	-0.01	-0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.02]
Min wind direction	-0.02	0.00	0.01	0.00	-0.01	-0.01	-0.01	0.02
	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.02]
Daylight (hours)	-0.96	2.32	0.38	-2.36	-2.58**	3.00*	0.47	7.23**
	[2.10]	[2.64]	[1.92]	[2.01]	[1.24]	[1.69]	[2.07]	[2.91]
Observations	22,944	22,403	22,944	22,403	22,944	22,403	22,944	22,403
R-squared	0.195	0.145	0.088	0.247	0.074	0.068	0.099	0.133

Notes: This table reports regression coefficients of the impact of various weather conditions on children's time allocation based on equation (1). Other explanatory variables include the child's characteristics, the mother's characteristics, household characteristics, local socio-economic background variables, state/territory dummies, postcode dummies, year dummies, month dummies, day-of-week dummies, and cohort dummy. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B16. Robustness checks - Correlations between air quality indicators and weather conditions

Weather variables	PM10 (1)	PM2.5 (2)	NO2 (3)	NEPH (4)	SO2 (5)	CO (6)
Precipitation (hourly average, 1/100 inch)	-15.46***	-4.96***	-0.32**	-0.32**	-0.14*	-0.05**
	[3.05]	[1.31]	[0.12]	[0.10]	[0.06]	[0.01]
Temperature (hourly average, 0^F)	-60.64**	-79.31**	-1.20	-4.59	0.71	-1.26
	[27.53]	[26.97]	[0.70]	[2.73]	[0.60]	[0.51]
Temperature squared	0.57***	0.65***	0.01	0.04	0.00	0.01*
	[0.19]	[0.18]	[0.01]	[0.02]	[0.00]	[0.00]
Relative humidity (hourly average, %)	-4.97	3.83*	0.22	0.35**	0.03	0.23***
	[4.28]	[1.72]	[0.13]	[0.12]	[0.02]	[0.02]
Wind speed (hourly average, miles/hour)	4.23	-5.92***	-1.57***	-0.28	-0.11	-0.12
	[2.68]	[1.07]	[0.20]	[0.16]	[0.06]	[0.07]
Wind direction (hourly average, degree to the north)	-0.12	-0.19	0.05	-0.01*	-0.01	0.01
	[0.55]	[0.18]	[0.05]	[0.01]	[0.02]	[0.01]
Observations	188,269	133,211	102,360	72,708	88,495	30,206
R-squared	0.059	0.090	0.293	0.087	0.036	0.175
Number of air quality stations	15	11	8	6	7	3

Notes: This table reports regression coefficients (multiplied by 100 for aesthetic purposes) from a FE regression of each of air quality indicators on various contemporary weather conditions. Unit of observations: hourly. Panel data on hourly air quality indicators and weather conditions are identified by three dimensions: hour-of-day (i.e., 24), day-of-year and air quality monitoring stations. Data: hourly air quality and weather conditions are from all air quality stations from the New South Wales's Office of Environment and Heritage. Sample: all stations with valid information on all included variables. PM10 (2.5) indicates hourly average particle matters less than 10 (2.5) micrometres in diameter [ug/m3]. NO2 denotes hourly average of Oxides of Nitrogen (in parts per hundred million (pphm)). SO2 represents hourly average of Sulphur Dioxide (in pphm) while CO stands for Carbon Monoxide (in parts per million (ppm)). NEPH denotes hourly average Nephelometer (visibility), reported in units of 10^{-4} m^{-1}. Other explanatory variables include year dummies (2017 and 2018, with 2016 as the base year), month-of-year dummies, day-of-month dummies and day-of-week dummies. Robust standard errors (multiplied by 100 for aesthetic purposes) clustered at the air quality station level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B17. Heterogeneity of weather impact – By child asthma and maternal working status

	Active activity				Media				Travel				Outdoor			
	Weekday		Weekend		Weekday		Weekend		Weekday		Weekend		Weekday		Weekend	
	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]
Separate estimation by:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Child asthma (Panel A)																
Max temperature (°F)	3.40***	3.97*	3.90**	9.41***	-0.40	-5.80**	-3.31**	-6.73**	0.49	-2.13	0.56	3.24*	3.20***	4.30**	9.06***	13.05***
	[1.28]	[2.24]	[1.68]	[2.94]	[1.11]	[2.42]	[1.29]	[2.66]	[0.75]	[1.84]	[0.92]	[1.70]	[1.20]	[2.13]	[1.71]	[2.82]
Max temperature sq.	-0.02**	-0.02	-0.02**	-0.06***	-0.00	0.04**	0.02***	0.05***	-0.00	0.02	-0.01	-0.02**	-0.01*	-0.02	-0.05***	-0.08***
	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]
Precipitation (inches)	-15.39***	-9.47	-19.40***	-2.71	0.17	13.23	20.25***	17.58	-5.83**	-4.13	-4.48	9.98	-28.83***	-11.02	-34.28***	-1.25
	[3.91]	[8.25]	[6.73]	[16.64]	[3.61]	[8.29]	[6.43]	[10.91]	[2.30]	[4.82]	[4.27]	[19.76]	[4.13]	[7.42]	[7.74]	[19.26]
Observations	14,785	4,784	14,983	4,765	14,785	4,784	14,983	4,765	14,785	4,784	14,983	4,765	14,785	4,784	14,983	4,765
Sample mean (minutes)	122.77	112.20	225.31	206.18	121.49	127.58	176.42	201.33	75.12	72.33	85.67	82.08	110.66	111.40	185.95	174.00
Unemployed mothers (Panel B)																
Max temperature (°F)	-3.43	4.73**	7.80***	5.27**	3.70*	-5.44**	-2.75	-4.73**	-0.65	0.93	-0.05	2.85**	0.56	3.24**	16.00***	10.15***
	[2.11]	[1.90]	[2.81]	[2.45]	[2.11]	[2.33]	[2.72]	[1.97]	[1.31]	[1.40]	[1.77]	[1.43]	[2.19]	[1.56]	[2.90]	[2.38]
Max temperature sq.	0.02	-0.03**	-0.05**	-0.03**	-0.03*	0.03*	0.02	0.04***	0.01	-0.01	0.00	-0.02**	-0.01	-0.01	-0.10***	-0.07***
	[0.01]	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.02]	[0.02]
Precipitation (inches)	-23.10***	-9.14	1.83	-4.95	8.87	-4.40	9.07	21.11**	-5.43	-11.20**	18.90*	-9.97	-15.89**	-24.56***	-3.93	-35.29***
	[7.31]	[7.02]	[13.78]	[9.68]	[7.10]	[5.68]	[8.83]	[8.48]	[3.81]	[4.48]	[11.46]	[7.27]	[6.99]	[6.04]	[18.53]	[10.40]
Observations	4,526	7,502	4,495	7,018	4,526	7,502	4,495	7,018	4,526	7,502	4,495	7,018	4,526	7,502	4,495	7,018
Sample mean (minutes)	114.85	156.46	208.18	228.95	116.41	121.63	189.16	156.74	75.23	83.25	88.72	89.37	109.53	97.86	173.99	156.99

Notes: This table reports the heterogeneous impact of temperature and precipitation on children's time allocation. Results for different sub-populations are obtained from equation (1). [a] "Yes" indicates the coefficient estimate in the regression for the sub-population mentioned on panel A or B while "No" represents the estimate for the other sub-population. Panel B: Unemployed mothers are compared with full-time working mothers. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Other explanatory variables: See Appendix Table B3. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B18. Heterogeneity of weather impact – By seasons and climate regions

	Active activity				Media				Travel				Outdoor			
	Weekday		Weekend		Weekday		Weekend		Weekday		Weekend		Weekday		Weekend	
	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]	No[a]	Yes[a]
Separate estimation by:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Winter months (Panel A)																
Max temperature (°F)	5.83***	1.95	2.84	4.99*	-2.65	-2.18	-6.20***	-4.87**	1.60*	-2.04	1.76	1.27	3.25**	3.06*	9.37***	15.61***
	[1.53]	[1.88]	[2.06]	[2.59]	[1.72]	[1.77]	[1.75]	[1.93]	[0.93]	[1.59]	[1.30]	[1.48]	[1.38]	[1.78]	[2.04]	[2.55]
Max temperature sq.	-0.03***	-0.01	-0.02	-0.03	0.02	0.01	0.04***	0.04***	-0.01*	0.02	-0.01*	-0.01	-0.01	-0.02	-0.05***	-0.10***
	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]
Precipitation (inches)	-13.78***	-10.74*	-19.80***	-2.55	1.37	-1.27	21.28***	7.93	-6.63**	-7.70**	-6.31	6.12	-18.60***	-25.41***	-27.61***	-17.70
	[4.62]	[5.87]	[6.84]	[10.12]	[4.23]	[5.43]	[6.59]	[7.47]	[2.72]	[3.48]	[4.74]	[8.68]	[4.18]	[5.02]	[8.14]	[12.34]
Observations	11,079	11,865	10,503	11,900	11,079	11,865	10,503	11,900	11,079	11,865	10,503	11,900	11,079	11,865	10,503	11,900
Sample mean (minutes)	141.62	132.39	227.92	223.33	114.35	113.66	166.05	169.22	81.17	78.51	90.78	87.91	110.73	97.29	176.47	167.18
Colder regions (Panel B)																
Max temperature (°F)	2.03	3.24**	2.36	1.35	-0.12	-2.66	-0.79	-6.16***	2.11	-0.59	3.36	1.36	2.38	1.76	8.28**	10.70***
	[2.75]	[1.49]	[3.52]	[2.27]	[2.30]	[1.68]	[2.88]	[1.77]	[1.61]	[1.02]	[2.17]	[1.34]	[2.82]	[1.43]	[3.76]	[2.03]
Max temperature sq.	-0.01	-0.01	-0.01	-0.00	-0.00	0.01	0.01	0.04***	-0.01	0.01	-0.02*	-0.01	-0.01	-0.00	-0.04	-0.07***
	[0.02]	[0.01]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Precipitation (inches)	-15.90***	0.69	-14.09	-13.66	4.60	-2.19	16.33*	26.04**	-5.86**	-9.62*	10.22	-13.12**	-25.10***	-8.12	-18.71	-27.85**
	[4.10]	[10.31]	[11.10]	[12.09]	[4.06]	[8.35]	[8.91]	[10.96]	[2.80]	[5.48]	[8.62]	[6.44]	[4.98]	[8.54]	[12.84]	[11.22]
Observations	7,637	7,776	7,381	7,370	7,637	7,776	7,381	7,370	7,637	7,776	7,381	7,370	7,637	7,776	7,381	7,370
Sample mean (minutes)	144.26	131.34	239.42	217.29	112.16	114.46	165.46	165.55	80.09	77.78	90.55	86.97	116.10	91.89	196.56	147.64

Notes: This table reports the heterogeneous impact of temperature and precipitation on children's time allocation. Results for different sub-populations are obtained from equation (1). [a] "Yes" indicates the coefficient estimate in the regression for the sub-population mentioned on panel A or B while "No" represents the estimate for the other sub-population. Winter months include June, July and August. Colder regions are those with latitude in the lowest third of all latitudes of postcode centroids observed in our main sample and warmer regions are those in the highest third. Sample mean indicates the mean value of each dependent variable in each group (in minutes). Other explanatory variables: See Appendix Table B3. Robust standard errors clustered at the month-year-postcode level in square brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.